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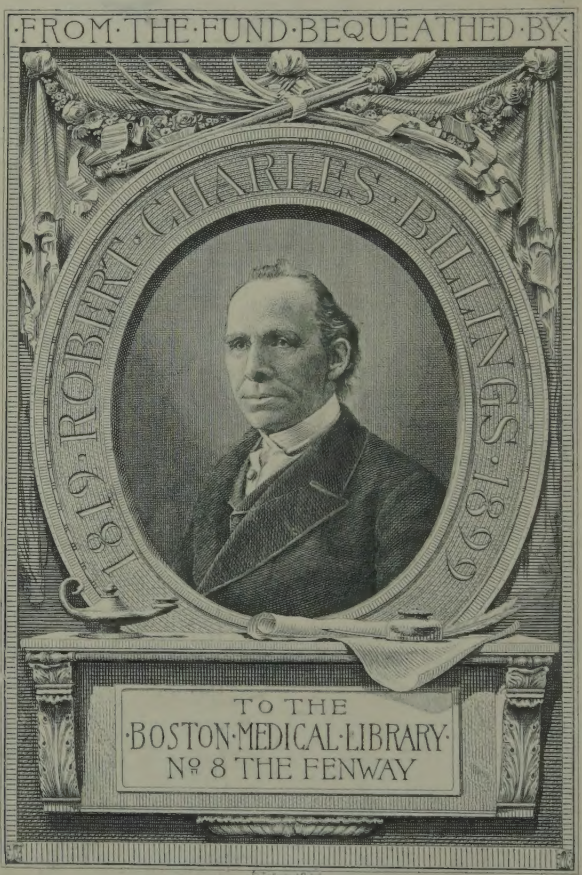
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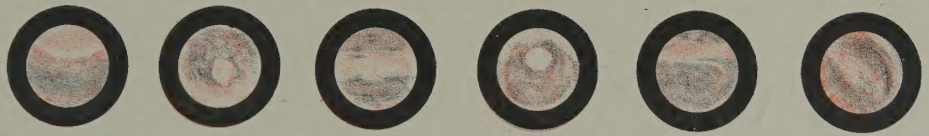
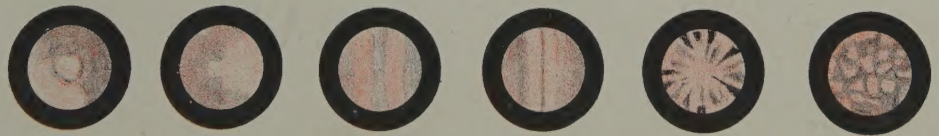


1 2 3 4 5 6

1. Crescent edge indicating that spheres are required for correction. Light moved upward with partial darkness following. 2. Central light area or image moved slightly downward with peripheral area of light due to spherical aberration moving upward. 3. Horizontal bar of light extending throughout the horizontal meridian and indicating astigmatism. If no movement of the bar endways can be noticed when the light is moved from side to side along the horizontal meridian, this meridian is corrected and the strength of the lens is marked at the end of a horizontal straight line. If the light is moved up and down, this bar will also move up and down, showing that the vertical meridian is not corrected. 4. Central light area or image moved slightly upward with the peripheral area of light due to spherical aberration moving downward. 5. This shows the same bar of light as seen in No. 3 moved upward. This vertical meridian should next be corrected until it is occupied by a vertical bar of light which cannot be moved up or down by tilting the mirror. The strength of the proper lens should be marked at the end of a vertical line crossing the horizontal one mentioned in describing No. 3. 6. This shows a faint bar of light axis 135. The faint shaded area on each side of the bar of light should be observed, the recognition of which often decides the presence of a low degree of astigmatism.



7 8 9 10 11 12

7 and 8. Illumination seen in conical cornea, revolving as around a pivot. 9. Scissors movement, bars of light separated. 10. Scissors movement, bars of light approximated, dark interspace fading. 11. Appearance in a case of irregular astigmatism with lenticular opacities or incipient cataract. 12. Appearance in a case of corneal irregular astigmatism.

PHOTOSCOPY

(Skiascopy or Retinoscopy)

BY

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PREFACE

PROBABLY every ophthalmologist is more or less skilled in the practical application of this objective test, but without a thorough understanding of its simple optical principles, the best results cannot be obtained. This book not only attempts to explain clearly its use, but also to elucidate the reasons of the various phenomena observed. In the diagrams light rays are represented as passing from one point of an illuminated area, instead of from two or more points, for the sake of clearness. Discussion of some minor details of little or no practical significance has either been very brief or entirely omitted, fearing that it might only confuse the student. The name of the test is considered in Chapter V.

The writer does not presume to detract from the teachings or writings of others, and has fully availed himself of material wherever found, especially acknowledging his obligations to the excellent works of Dr. Edward Jackson and Dr. James Thorington. He also takes sincere pleasure in acknowledging the extremely kind and ready assistance of his brother, Dr. D. W. Stevenson of Richmond, Indiana, his associate, Dr. E. L. Mather, and his assistant, Dr. E. M. Weaver.

M. D. S.

AKRON, OHIO, *August*, 1906.

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PHOTOSCOPY.

CHAPTER I.

DEFINITION.—VALUE.—SUGGESTIONS FOR BEGINNERS.—NECESSARY INSTRUMENTS.

Definition.—Photoscopy is the method of estimating the refractive error of an eye, by reflecting light into it by a plane or concave mirror, while rotating or tilting the mirror, and observing the size, shape, brilliancy, direction, and rate of movement of an area (image) of light apparently in the observed eye.

This light area is a more or less magnified and distinct image of the light illumination on the retina, and is formed by those rays of light from this bright retinal illumination which pass out of the observed eye and enter the examiner's eye.

Unless the examiner is located at the anterior focal point of an eye (that point in front of an eye where rays of light passing out of it focus, or are focused by lenses), many rays of light pass out of the patient's pupil that do not pass into his. The area of the pupil of the observed eye through which these rays pass appears slightly dark, and is said to be in a shadow. The light rays passing through this dark portion of the observed pupil, which surrounds the bright central area or image, to the examiner's eye, are reflected from the dimly illu-

minated portion of the retina. All other rays which pass from the observed to the observer's pupil, forming the central image, are reflected from the bright illuminated portion of the patient's retina.

The central light area, sometimes called spot or image, is always projected (appears to be) in the direction of that area in the pupil of the observed eye through which light from the retinal illumination passes to the examiner's eye.

The area or image of light does not any more resemble its source—the true light illumination on the retina—in size, shape, or location, than the image of an object resembles the object when seen through a powerful convex lens. It may be of different size or shape, and be situated immediately in front, above, below, or on one side of it, depending on whether it is viewed through the middle, upper, lower, or lateral portion of the lens.

Value of Photoscopy.—The value of photoscopy is based upon the following facts:

1. The character of the refractive error, if any be present—*e. g.*, myopia, hypermetropia, astigmatism—is quickly diagnosticated.

2. Even those who are not expert in this method can obtain approximate results more quickly than by any other.

3. It saves much time.

4. It requires no expensive or complex apparatus.

5. No questions need be asked of the patient.

6. It is an objective test, practically made without the patient's coöperation, and wholly independent of his age, intelligence, visual acuity, or indifference.

7. It is by far the most accurate objective test of the present day. By an expert operator nearly always

fair, and very frequently absolutely correct, results are obtained.

8. It inspires the confidence of the patient, and dispels the anxiety of examiner and patient, when the latter sees satisfactorily through the properly adjusted correcting lenses.

9. It gives a good idea of the refraction through particular areas of the pupil, which is often very important. In some cases it may be a help as to proposed operative measures,—*e. g.*, the best position for an optical iridectomy.

10. By it we can determine objectively the amount of the accommodation, the knowledge of which is of special service in examining children,—*e. g.*, in post-diphtheritic paralysis of the ciliary muscle.

11. It is indispensable in examining young children, the feeble minded, and the illiterate; also in nystagmus, amblyopia, and aphakia. In examining stupid young or old people who insist upon describing everything they see, and some things they do not, or who have a fondness for reading the test types over and over again from the top to the bottom, this test is a friend in time of need.

12. It is simple; any one with ordinary skill and qualifications can quickly learn its principles and correct application.

Suggestions for Beginners.—1. Be patient and persevere. Proficiency in this method is acquired only after long practice and constant application.

2. Give careful attention to details.

3. Be content to learn step by step, one thing at a time, and be sure to know the reason why for everything.

4. You will be much benefited by following the experiments and observations mentioned throughout this work.

5. Do not fail to study the references.

6. Become thoroughly familiar with the laws of refraction (Dioptrics) and reflection (Catoptrics).

7. Remember, that without a good understanding of the underlying principles the test must remain a blind routine and can never be of the highest utility. The fundamental groundwork must be understood before the test can be appreciated.

8. It is wise to begin the study of the test under known conditions. Any of the many schematic eyes on the market can be used for this purpose, or one can easily be made.

9. After studying this volume thoroughly, and performing the simple experiments advised therein, examine a series of ordinary eyes with known refractive defects, such as simple myopia, hypermetropia, or astigmatism. Be careful to follow every detail, and make a close study of the areas of light and darkness in the pupil under as many different conditions as possible,—*i. e.*, with different sizes of the light aperture in the chimney; with the source of light at different distances from the mirror; with the mirror at different distances from the patient; and with different lenses before the eye to be examined.

10. The question often arises: Should the ophthalmologist wear lenses while performing this test? The writer will answer this question by stating that the examiner's distant vision should be at least $\frac{6}{6}$. This should, if possible, be obtained by accommodating, rather than by the aid of correcting lenses, since they re-

flect more or less of the rays of light; but, if the vision is much better with lenses than without, they should be used. The examiner does not need to take any note of his own accommodation, as he must do in practising ophthalmoscopy for like purposes.

Necessary Instruments.—1. *The Photoscope, or Mirror.*—Many varieties of the photoscope are in use. They should all have a good-sized round handle, four or five inches long and from one-fourth to one-half inch in diameter. Some prefer a mirror with a small, folding, protecting handle, or two mirrors, so made that one may serve for the handle while the other is in use. These are easily carried in the pocket, but the writer much prefers one with a long handle, because it is easier to hold and manipulate, the handle lying in the hollow of the hand and the index finger resting against the edge of the disc, thus giving better control of the instrument; while in holding the other styles, the fingers are cramped.

The silvering on the mirror should be free from imperfections and flaws, so that the reflections may be as nearly perfect as possible. If the mirror is perforated in the center, the light rays pass freely to the examiner's eye, but the edge of the perforation, unless perfectly blackened and free from chipping, causes very annoying reflections. These objections are practically overcome when the mercury or plating alone is removed; but, even then, the glass intercepts and reflects some of the light that otherwise would pass from the observed to the examiner's eye. The central dark shadow, noticed especially when the light is reflected on a white surface, is more marked the larger the perforation, but is almost eliminated by having, instead of a perforation,

only a small area of the mercury removed, because the unbroken surface of the glass also reflects some light. Where the mercury only is removed, that portion of the glass uncovered must be kept especially clean.

The following varieties are preferred by the writer in the order mentioned, although many others are on the market:

(*a*) A plane mirror 2 centimeters in diameter, with a 2-millimeter sight-hole made by removing the quicksilver rather than by perforating the glass (and this applies to all mirrors), mounted on a plain black metal disc 4 centimeters or more in diameter, so as to be large enough to shade

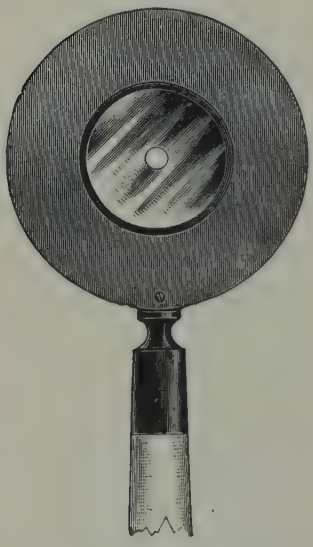

FIG. 1.—Thorington's small plane mirror.

FIG. 2.—Large plane or concave mirror.

the eye from the light. This is the most useful form when the source of light is near the mirror (Fig. 1).

(*b*) A plane mirror about 4 centimeters in diameter with a 2- or 3-millimeter sight-hole. This is the most useful form when the source of light is behind the patient's head (Fig. 2).

(*c*) A concave mirror about 4 centimeters in diameter with a 2- or 3-millimeter sight-hole (Fig 2). It is well to have this and one of the plane mirrors mentioned above, although a plane mirror is all that is necessary.

Fig. 3.—Electric light with twisted carbon.

2. The *Light.*—This should be as white, clear, and steady as possible.

(*a*) The Welsbach mantel is best, although easily broken.

(*b*) The argand burner is used by many surgeons.

(*c*) The electric light with a spiral carbon, inclosed in frosted glass and covered by a hood with a round opening (Fig. 3), is excellent.

3. *An Adjustable Bracket.*—(*a*) An extension bracket that may be swung within a radius of several feet, having a vertical adjustment of at least 8 inches. This is necessary when the bracket is attached to the wall behind the patient. It is easily moved and probably the most useful form—manufactured by F. A. Hardy & Co., Chicago (Fig. 13).

(*b*) One of the smaller, commoner, and somewhat

cheaper brackets will answer if it is attached to the wall at the examiner's side, or to the wall behind the patient, if it is preferred to work with the light at that distance.

4. A *cover chimney*, or *light screen*, to shade the light, regulate its amount, and also to diminish the heat. When using the light behind the patient's head this is not absolutely necessary, but desirable, with either the plane or concave mirror (Fig. 4).

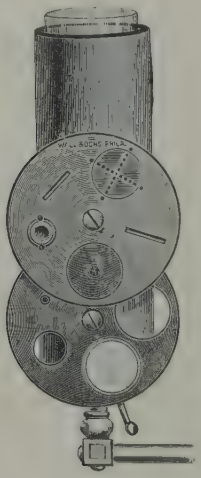

FIG. 4.—Thorington's asbestos chimney.

FIG. 5.—Thorington's asbestos chimney with iris diaphragm.

(*a*) One made of $\frac{1}{8}$-inch asbestos, 6 centimeters (about $2\frac{1}{4}$ inches) in diameter by 21 centimeters ($8\frac{1}{4}$ inches) in height, to fit over an ordinary gas-lamp chimney. It has a 30-millimeter opening placed opposite the brightest part of the light and covered by an iris diaphragm, which is controlled by an ivory-tipped lever moving on an index, regulating the size of the opening from 2 to 30 millimeters (Fig. 5). (Thorington, *Jour. Amer. Med. Assoc.*, 1898, p. 1378.)

(*b*) A simple asbestos screen, but with an uncovered 5-millimeter opening. This is generally all that is necessary in working with the light close to the mirror. A mica chimney is cheaper, and stands the heat better than one of glass, hence is better to use next the flame with either of the cover chimneys (Fig. 6).

5. *The Examiner's Protecting Shade.*—When working with the light close to the mirror, a shade is needed to protect the examiner's eyes from the bright light which otherwise must flash into the unused eye while using the mirror before the other eye, no matter how small the opening in the cover chimney. By holding a book about five or six inches away from a 5-millimeter opening the size of the area of light projected on it may be noticed.

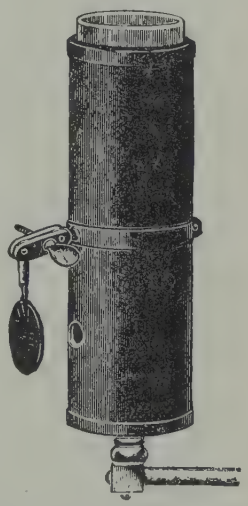

Fig. 6. — Plain cover chimney and author's shade.

I have made a small shade (*Ophthalmic Record*, Feb., 1904), black on one side, with a mirror on the other side, which is so placed as to reflect light on the trial case, as well as to shade the observer's unused eye. If preferred, the shade can be made a dull black on both sides. The shade is supported by a ball-and-socket joint device which may be attached to any cover chimney, and is easily placed in any position. It is indispensable for the good of the test and the comfort of the examiner when working with the light close to the mirror—manufactured by F. A. Hardy & Co. (Figs. 6 and 13).

6. *A Good Ordinary Trial Case.*—It is a great advantage to have one with a large number of different spheres. The lenses should be clean, and as free from scratches as possible. I had a trial case made by the Julius King Opt. Co., containing 44 pairs each of convex and concave spheres and 31 pairs each of convex and concave cylinders (*Ophthalmic Record*, Jan., 1906). The handles, which have the strength marked on each side, are provided with a screw so that the lenses may be turned or new ones introduced. The cylinders have no ground opaque sides, the axis being indicated by two small whitened holes near the margin, which one may very readily see in any light. The prisms are likewise marked, except that there is only one whitened hole indicating the apex.

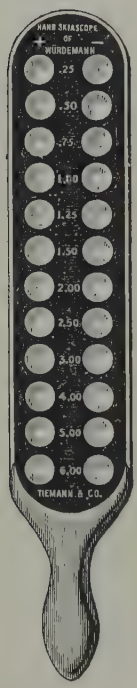

FIG. 7.
Würdemann's disc.

7. A good simple *trial frame*, one that may be properly adjusted before the eyes, so that the patient will see through the center of the inserted lenses, and yet not allow them so close as to touch the lashes or become covered with moisture. The writer has a set of simple drop trial frames, each with a quite different nose piece, with the degrees plainly marked in white on blackened steel. These are the simplest, lightest, and most satisfactory trial frames made.

8. *Meter Stick.*—Every one should have a meter stick, graduated on the edge in dioptric focal lengths.

I have a three-sided meter stick graduated in the metric system, in inches, in dioptric focal lengths, and also giving a tangent scale with which to measure the degrees of squint, etc. One side gives the dioptric focal length of the minus sphere to be added to the result found at the working distance in this test. A measuring tape may also be employed, attached to the trial frame or lens disc (Burnett).

9. *A Dark Room.*—It must be one from which all light can be excluded, so that none reaches the eye to be examined, or the mirror, either directly or by reflection from other objects, except that which arises from the light in use, thus making darker the portion of the retina surrounding the bright illumination. This room should be as large as possible. Small closets and sweat boxes are not conducive to good work, and exhaust both examiner and patient. The general examination room darkened by close-fitting shades is usually the best obtainable.

10. Dr. H. V. Würdemann (*American Journal of Ophthalmology*, 1891, p. 223) described a very convenient although not absolutely necessary instrument, called *Würdemann's disc*. One side contains convex and the other concave lenses. It is reversible, and can be raised or lowered by the patient or an assistant, allowing different lenses to be placed before the eye. Its smooth broad edge rests against the side of the patient's nose (Fig. 7).

CHAPTER II.

UNDERLYING PRINCIPLES.—PRINCIPLES OF PHOTOSCOPY.—BRILLIANCY OF THE LIGHT IN THE PUPIL.—DEGREE AND RATE OF MOVEMENT.—MATHEMATICAL POINT OF REVERSAL.—EXPERIMENTS AND OBSERVATIONS.

Underlying Principles.—1. It is the light reflected from a non-luminous object which makes it visible. Therefore, the manner in which the reflected light reaches the eye is of more importance by far than the manner in which the light reaches the object.

2. Any visible object may be said to be composed of one or more points, and from each of these points, rays (waves) of light are reflected in every direction. If the object consists of only one point, then there is but a single cone composed of countless rays of light. The base of this cone fills and rests in the pupil of the eye; the apex is at the object. (The light rays are gradually refracted by the different media through which they pass, the secondary rays crossing the axial ray between the nodal points at the optic center and not exactly in the plane of the pupil, although it is better, for the sake of simplicity, to consider them as being bent in this plane.) If an object is composed of many points, then there are as many cones as points in the object. When a point in a visible object is situated at a distance of twenty feet or more, the rays of light passing into the eye from that particular point are so nearly parallel (so-called parallel rays) that instead of forming a cone

they may be considered as forming a cylinder or solid rod of light.

3. Parallel rays of light are focused on the retina of an emmetropic eye, forming a cone within the eye (like the sharpened end of a lead pencil) The base fills the pupil; its apex rests on the retina. In this condition the rays of light from a point in space are focused as a

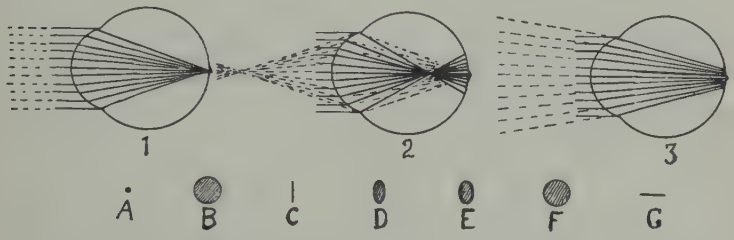

FIG. 8.—1, The fine black lines represent parallel rays of light entering an emmetropic eye and focusing on the retina. The dotted lines represent the same rays reflected by the retina and passing parallel to their source. 2, Parallel rays of light, after entering a myopic eye, focus before reaching the retina, and crossing one another at the focal point, form a round area of light on the retina. The dotted lines show how the reflected rays pass out of the eye from any one of the points of the retinal illumination (central portion of the illumination in this case) and come to a focus outside the eye, where they cross and form another cone of light. 3, The black lines represent parallel rays entering a hypermetropic eye and they are seen to impinge on the retina in circular form. The dotted lines represent the rays reflected from the retina which pass divergingly into space. A and B show the two forms of retinal illumination in an emmetropic, simple hypermetropic, and myopic eye. C, D, E, F, G, different forms of retinal illumination found in cases of astigmatism.

single point on the retina. Rays of light reflected from this particular point will again pass off or out of the eye parallel, filling the pupil and forming a cylinder in space (Fig. 8[1]).

4. Parallel rays of light passing into a myopic (long) eye, are focused before reaching the retina, and cross at this focal point, forming a secondary cone. Therefore, in this condition there are two cones within the eye, their apices a common point. The base of one cone

fills the pupil; the base of the other rests in a circular form on the retina. In this condition, a point in space is represented by a diffusion circle on the retina, and the light reflected from a point in this circular area will pass out, filling the pupil, and come to a focus (anterior focal point) somewhere in space. It forms a cone whose base rests in the pupil, and whose apex corresponds to the anterior focal point of the eye. The light rays, after crossing at this anterior focal point of the eye (apex of this first cone), form a second cone whose apex joins the apex of the first cone, and whose base, therefore, rests in infinity (Fig. 8^2).

5. Parallel rays passing into a hypermetropic (short) eye reach the retina before focusing and form a truncated cone or frustum, the large end of which fills the pupil; the small end rests as a diffusion circle on the retina. In this condition, a point in space is also represented by a diffusion circle on the retina, and the light rays reflected from a point in this circular area pass into space divergingly, forming a truncated cone, its base at infinity, its smaller end filling the pupil (Fig. 8^3).

6. In regular astigmatism, the light passing into an eye never strikes the retina as a point (a focus) and only as a circle in certain cases of mixed astigmatism. It is practically always between these two, either a line or any gradation from a line to nearly a circle (Fig. 8, C, D, E, F, G). If parallel light rays passing through any meridian are exactly focused on the retina, the returning rays through that meridian will pass off as parallel rays to their original source. In hypermetropic or myopic meridians this is not true. In hypermetropic meridians they will pass off divergingly; in myopic,

convergingly; in both cases reaching their source modified by these conditions of refraction (Fig. 8).

7. In myopia, the light passing from an illuminated point on the retina (a point of the so-called retinal illumination) forms a cone outside the eye, its base filling the pupil, its apex at the anterior focal point of the eye (Fig. 8^2). This point is at once the far and (unless the eye accommodates) near point of the eye. It is the only point at which the eye can see clearly without changing its refractive strength,—the point for which the eye is focused. This point is the conjugate focus of the retina, or the point where light starting from the retina would focus (the so-called point of reversal). Light rays passing from a point on the retina through any myopic meridian will focus in front of the eye at the anterior focal point of that meridian. These rays form a triangular sheet of light outside the eye, its base at the pupil in that meridian, its apex at the anterior focal point of the same meridian.

8. The position of the apex of the cone can be changed; or, which is the same thing, the anterior focal point of the eye in myopia, or the anterior focal point of any myopic meridian. It is moved closer to the eye by convex (+) spherical lenses, or caused to recede by concave (—) spherical lenses placed in front of the eye.

The light rays passing out from any eye, whether passing parallel as in emmetropia, or divergingly as in hypermetropia, can be made to focus at different distances in front of the eye by means of convex (+) spherical lenses placed in front of it. This produces an artificial myopia.

9. By means of photoscopy the examiner can tell

whether or not the light passing through any particular meridian of an eye has focused before reaching his eye. In case it has focused before reaching his eye, it can be made to focus at his eye by means of concave (—) spherical lenses, or by the examiner moving forward to the focal point. In case the light rays have not focused before reaching his eye, they can be made to do so by the use of convex (+) spherical lenses. In other words, the examiner can, at all times, tell whether the rays coming out of an eye have or have not crossed before reaching his eye. They can be made to cross at his eye by means of the proper spherical lenses, or sometimes by changing his position, or both.

10. When light strikes a mirror or a reflecting surface perpendicularly, it is reflected in the same general direction whence it came. Light passing into an eye from directly in front strikes the retina perpendicularly, and is reflected in the same general direction, only necessarily somewhat diffused. Of course, the retina, chorioid, sclerotic, and nerve ending are not perfect reflecting substances,—all these absorb some of the light,—and, their surfaces not being smooth, reflect part of the light into every portion of the interior of the eye. So, when a mirror throws light into an eye, some of the light will be reflected back to the mirror. If the rays reflected through the patient's pupil focus at the mirror, they can be seen by the examiner's eye only when directly behind its sight hole (Fig. 16). But if they are diffused, as in high degrees of ametropia, they can be seen sometimes at the side of the mirror.

11. Light from a source above a window will pass into a room in a downward direction, illuminating the floor or lower part of the wall opposite. Conversely,

light starting from the lower part of the room will pass out of this window into space in an upward direction. Hence, a person standing outside of the room could see the light on the floor only by being above the level of the window.

12. Light passing into a room from a source lower than the window will illuminate the upper part of the wall, or ceiling. The light, when again reflected out of the room, can be seen only from below.

13. When a lighted lamp is seen through a window, the light does not appear to occupy the whole window, but only a part of it. It appears to occupy only that part through which the light is seen. This part may change to as many different sections of the window as there are positions from which the light is visible. Light rays pass from the lamp out of every part of the window. If a large convex spherical lens were placed before the window, bringing all these rays of light to a focus, then, viewed from that point, the whole window would appear occupied by one large light, because light from every part of the window would enter the eye. However, if the observer were not at the point of focusing, only a part of the window would appear to be occupied by a light. This part would change its location as he changed his position in front of the window, or as the light was moved. If the observer looked directly through the center of the lens at a light, a magnified image of it would be seen in the same direction. But if he looked through any peripheral portion of the lens a magnified image of the light would be projected in a different direction from the true position of the light, because all spherical lenses have a prismatic effect when rays of light pass through their periphery. If he

looked through the upper portion of the lens, the image would be displaced upward; if through the lower, downward.

14. If the eye is likened to a room, the pupil being a round window, the retina forms the back and sides of the room. The light in entering an eye always passes through every portion of the whole pupil; and, in being reflected out, likewise passes through every portion. Light coming from a source above the center of the pupil strikes the retina below its center, and the light from below impinges on the retina above. Neither the lens nor the other refractive media change this general statement.

15. Consider this light on the retina (retinal illumination) as a lamp placed in the eye, for it is the source of light that passes to the examiner's eye in this test. If this retinal illumination is above the central part of the retina, the general direction of the light passing out of the eye will be downward. But if it is below, the light will pass upward; if on the right, light will pass to the left; and if on the left, then toward the right.

16. The part of the window, or pupil, that appears brightly illuminated is the part through which bright light rays pass to the observer's eye. The dark portion is the part through which the light reflected from the retinal illumination does not pass into his eye but into space. The only rays which do pass through this dark portion of the pupil and enter the examiner's eye are those which come from the dimly illuminated portion of the retina immediately surrounding the bright retinal illumination.

Principles of Photoscopy.—Recalling the illustration in which the eye was likened to a room, and the

pupil to a window of this room, the use of the different forms of mirrors in reflecting light through the pupil into the eye can now be considered.

When a plane mirror is held perpendicularly in front of an eye and on a level with it, only rays of light which are reflected from the central portion of the mirror enter the observed eye. Now, if the mirror be tilted downward, the light on the face moves down, and only

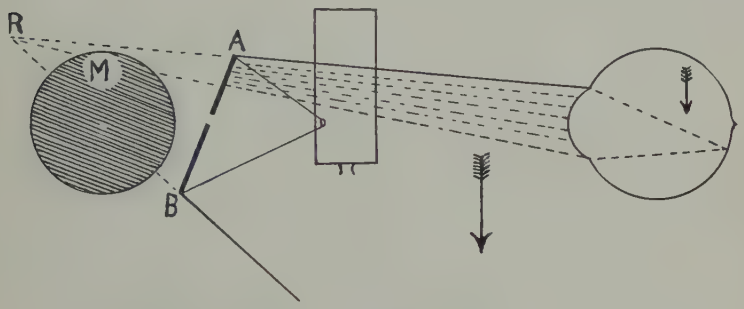

FIG. 9.—Plane mirror tilted downward. AB, plane mirror tilted downward, reflecting the light coming from the aperture in the cover chimney down on the face, as indicated by the large arrow, and down on the retina, as indicated by the small one. The light which enters the pupil, when traced back by the dotted lines, comes only from the upper part of the mirror, as in M. The image of the light, or apparent source of light, is erect, since the rays forming it have not crossed, and is apparently situated behind the mirror in the direction from which the rays enter the eye. The distance between the mirror and R (the image) should be the same as between the mirror and the source of light, but if made so the diagram would be less effective in some other particulars.

the upper rays of light, which are reflected from the upper part of the mirror, enter the patient's eye. If the patient is asked in what portion of the mirror he sees the light, he will answer that he sees it in the upper, for the reason that the tilting has caused the apparent source of light, or image of the light in the mirror, to move from the central to the upper portion (Fig. 9). The light which enters the patient's eye comes from above the central portion of the pupil, and therefore

must impinge on the retina below its center. The mirror has been tilted downward; the light on both face and retina has moved down.

Exactly the reverse is obtained when the mirror is tilted upward. The apparent source of light is now seen by the patient in the lower portion, and the light which enters the eye comes from the same portion, which is below the center of the pupil; therefore, it must im-

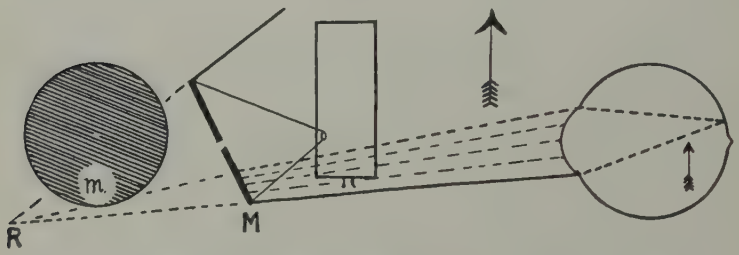

FIG. 10.—Plane mirror tilted upward. The large arrow indicates the movement of the light on the face, the small one of the retinal illumination, both being in the same direction. The light which enters the patient's eye, indicated by the dotted lines, comes directly, without crossing, from the lower part of the mirror, and hence the apparent source of light or erect image of the light is seen by the patient in the lower part of the mirror M, and apparently behind it at R. Note that in Fig. 9 the light entering the pupil is reflected by the upper part of the mirror, and in this by the lower, giving the same result as if a light had been lowered in front of the eye, thus raising the retinal illumination. The distance between the mirror and R should be the same as between the mirror and the source of light. (Explanation in Fig. 9.)

pinge on the retina above the center. The mirror has been tilted upward, and the light on the face and retina has moved in the same direction (Fig. 10).

If the light rays extending from the apparent source of light to the retina are likened to a lever, the pupil to the fulcrum, and the mirror to the power arm to raise and lower the external end or apparent source of light, it will be seen that the retinal or internal end must move in the opposite direction.

No matter what the refractive condition of the eye may be (myopic, hypermetropic, astigmatic, or emmetropic), light passing from a plane mirror, when it is tilted in any direction, causes the light on the face and that on the retina (retinal illumination) to move in the same direction (Figs. 9 and 10).

The image of any object seen in a plane mirror is apparently as far back of the mirror as the object is in front of it; therefore, the image of the light seen in the mirror by the patient is apparently as far back of the mirror as the source of light is in front of it. The light enters the patient's eye from the same direction and distance, in exactly the same manner as if the light were placed at the apparent source (image of light in the mirror). In other words, the light enters the patient's eye from a distance equal to the distance from the patient's eye to the mirror plus the distance from the mirror to the source of light. The amount and brilliancy of light entering the patient's eye is in inverse ratio to the square of the distance of the apparent source of light, or image of the light in the mirror, from the eye. For example: if the apparent source of light is at 2 meters, there is four times as much light as when it is at 4 meters, or twice the distance. If the mirror is 1 meter distant from the eye, and the source of light 1 meter from the mirror, then the image, or apparent source of light, is 2 meters from the eye. Now, if the light is moved 3 meters from the mirror, the position of the mirror remaining exactly the same, or, on the other hand, the mirror moved 2 meters from both patient's eye and lamp, the image (or this apparent source of light) will be 4 meters from the eye. In either case it is twice as far as in the first instance, and, as the square of

two is four, there will be only one-fourth as much light passing into the eye.

It has already been stated that the light enters the patient's eye as if it came from the image, or apparent source of light in the mirror. If the anterior focal point, or conjugate focus of the retina, and the apparent source of light should coincide—*i. e.*, be located in the same spot—the light would focus on the retina and give a small bright area of retinal illumination, which would reflect the light better, and give a more distinct anterior focal point than a large and less brilliant illumination. Therefore, when working near the anterior focal point, it is desirable that the apparent source of light should be as near this position as possible. The brighter the source of light and the nearer the apparent —not the real—source is to the eye the more light enters the eye. The closer the apparent source of light is to the anterior focal point the more nearly the light focuses on the retina, or the smaller is the retinal illumination.

When a concave mirror is held perpendicularly in front of, and on a level with the eye, but at a distance greater than its focal length, only the central rays of light enter the eye. These rays come from the central portion of the mirror. Now, if the mirror is tilted downward, the light on the face moves down, as it did with the plane mirror. But, unlike with the latter, the apparent source of light, or image of the light, which is situated in front of the mirror also moves down. The upper rays on the patient's face which pass into the eye, if traced back, come from the lower part of the mirror, and having crossed, the patient on being asked will say that the image of the light is in the lower part of the mirror.

The light reflected from the lower portion of the mirror is focused with that coming from other portions, and passes from below through the pupil in an upward direction, impinging on the retina above its center. If the concave mirror is tilted downward, the light on the face moves down, but that on the retina up (Fig. 11).

If the mirror is tilted upward, the apparent source of

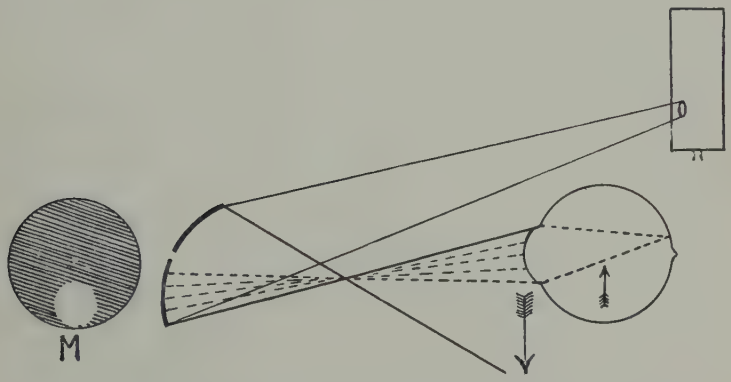

FIG. 11.—Concave mirror tilted downward: The large arrow indicates the movement of the light on the face, in the same direction as with the plane mirror, but is opposite to the direction of the small arrow, indicating the movement of the light on the retina, or the retinal illumination. The reason for this difference between the plane and concave mirrors is that while the upper part of the light at the face enters the pupil in each case, with the plane it is reflected directly from the upper part of the mirror, but with the concave from the lower part, having crossed. The apparent source or image, which is inverted because the rays forming it have crossed, appears to be in the lower part of the mirror, and in front of it, near its focal point. M shows the part of the mirror which reflects the light.

light moves up, and the light passes into the eye in a downward direction, coming from the upper portion of the mirror and impinging on the retina below the center. If the concave mirror is tilted upward, the light on the face moves up, and the light on the retina moves down (Fig. 12).

With the concave mirror, unless its focal length is

very short, the focus of the light, or apparent source of light, is close to the patient's eye, and therefore a large amount of light will pass into the eye. In using the plane mirror, the light on both face and retina moves in the same direction, thus corresponding with the movements of the mirror. But, with the concave mirror, the light on the face moves in the same direction, while the light on the retina moves in the opposite direction to the

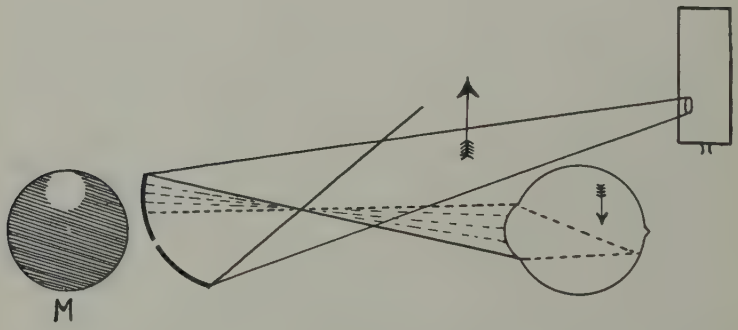

FIG. 12. — Concave mirror tilted upward: The large arrow pointing upward and the small one downward show that the light on the face and retina moves in opposite directions. The lower part of the light on the face enters the pupil as with the plane mirror (Fig. 10), but comes from the upper part of the mirror, having crossed, as shown by the dotted lines. The patient sees the image, apparent source of light, in the direction of the upper part of the mirror and near its point of focus. The image is inverted, because the rays forming it have crossed. M shows the part of the mirror which reflects the light.

movement of the mirror. To repeat,—the light on the retina moves in the same direction as the light on the face with the plane mirror; but in the opposite, with the concave, in any eye (Figs. 9, 10, 11, and 12).

Not only the means but also the manner in which the light enters the patient's eye and impinges upon the retina have been carefully considered. The more important part of this test can now be taken up,—*i. e.*, the

manner in which the light, reflected from the patient's retina, passes to the examiner's eye.*

Consider the light illumination on the retina as a small lamp placed at the back of the eye, which can be moved up and down or from side to side, by tilting the mirror. It is now important to learn how the light passes out of the eye from this retinal lamp, or illumination. It will be well, for a time at least, not to think of how the light entered the eye to form this retinal illumination (which has just been considered), as it has practically nothing to do with the manner of its exit.

The light passes out of the eye through every portion of the pupil, no matter whether this is from the single point of a perfect focus of light on the retina or from each of the several points of a so-called imperfect focus. These rays of light will either focus in front of the eye or pass parallel or divergingly into space, and in every case will form an area of light, large or small, at the observer's face. Some or all of these rays will pass through the aperture of the mirror into the observer's eye.

The same laws govern the light in passing out as were observed in our consideration of light passing into the eye,—*i. e.*, if the retinal illumination is above the center of the retina, the light rays will pass out in a downward direction; if below, in an upward direction; if to the left, then to the right; and, if to the right, then to the left.

The observer is concerned only with the *central* light image or spot apparently in the pupil of the observed eye, in considering its apparent size, shape, brilliancy, and rate of movement. This portion in the observed eye, which appears light to the examiner, is in a direct

* In this connection the sight-hole in the mirror need not be considered.

line from his nodal point to that part of the pupil through which the light from the real retinal illumination passes to enter the examiner's eye; it is simply projected in the direction from which the rays of light come. The apparent darkness which surrounds the central light area in the pupil of the observed eye appears dark only because the bright light from the retinal illumination, although passing through this area of the pupil, does not enter the observer's eye. The few rays of light which do pass through the dark portion of the pupil into the examiner's eye, as before stated, are reflected by the dark or dimly illuminated portion of the retina which surrounds the bright retinal illumination. The dark part of the pupil might be termed a poor image of a portion of the dimly illuminated retina.

In the remainder of this book, the rays of light passing from the bright illumination on the retina will alone be considered. And, in order to make the test simpler and easier to understand, it will be assumed that the portion of the retina surrounding the bright retinal illumination is in complete darkness, and that no light rays are reflected by it through the dark portion of the pupil into the examiner's eye.

If the whole retina were equally illuminated, the whole pupil would appear equally filled with light, as the observer would see a magnified image of some portion of the illuminated retina through every part of the pupil. But, since in the test only a small part of the retina is brightly illuminated, only that part of the pupil appears brightly lighted through which the image of this portion of the retina is seen.

The diagrams in this book, for the sake of clearness, represent the retinal illumination as a mere point of

light, but this illuminated area is usually either round or elliptical in shape with a more or less blurred margin between the brighter central and surrounding dark portion of the retina. The light, passing through the pupil to the examiner's eye, comes from this more or less blurred-edged disc of light on the retina, and the observer finds it more difficult to distinguish the dividing line between the central area and surrounding shaded area when the margins of the central bright area are not defined. Hence, it is important to have a small and bright retinal illumination, and the remainder of the retina as little illuminated as possible, with as distinct a margin between the illuminated and dark portions as can be secured.

When all the rays of light passing out of the patient's eye focus in the examiner's eye, or are focused there by spherical lenses, he being at the anterior focal point, the pupil of the observed eye will necessarily appear brilliantly illuminated as a bright, large, central light area. Since there is no dark portion with which to compare this light area, no movement of this area is apparent (Fig. 16).

If the rays of light are not brought to a focus at the examiner's eye, only a part of them enter his eye.

The following phenomena will be observed when the rays of light have not focused before reaching the examiner's eye,—*i. e.*, when the anterior focal point (if there be one) is behind the examiner, always indicating that a convex (+) spherical lens is required for the correction, as in hypermetropia and emmetropia, or myopia when the anterior focal point is situated at a distance greater than that of the examiner (Figs. 14, 15, 17, and 18).

1. Only a certain number of the rays of light, reflected from the retinal illumination and passing out of the pupil, enter the examiner's eye.

2. The rays passing from the retinal illumination, which do enter the examiner's eye, pass through that portion of the pupil which alone appears brightly illuminated (light area or image). This light area is simply projected in the direction of the rays of light, like any image seen through a lens or prism.

3. The bright rays which do not enter his eye pass through that portion of the patient's pupil which appears dark—the so-called shadow.

4. The portion of the pupil which appears illuminated corresponds in position to the situation of the examiner's eye in the area of light at the examiner's face, and also to the location of the illumination on the retina from which these rays come. Thus, if the retinal illumination is above the center of the retina, the rays pass out in a downward direction. Only the upper portion of these rays enters the examiner's eye and passes through the upper portion of the patient's pupil, which part alone appears brightly illuminated (Figs. 15 and 18).

If the rays of light have focused before reaching the examiner's eye, forming an anterior focal point in front of his eye, between him and the patient, as in high degrees of myopia, it indicates that a concave (—) lens is required for correction. At the anterior focal point the rays cross,—the lower rays now become the upper, and the upper the lower; the right the left, and the left the right ones (Figs. 19 and 20).

In this condition the following will be observed:

1. Only a certain number of the total rays of light reflected out of the patient's pupil enter the examiner's eye.

2. The bright rays of light which enter the examiner's eye pass through that portion of the pupil which alone appears brightly illuminated.

3. The bright rays of light which do not enter the observer's eye pass through that portion of the pupil which appears dark.

4. The illuminated portion of the pupil does not correspond in position to the situation of the examiner's eye in the area of light at his face, neither to the location of the illumination on the retina from which these rays come. That is to say, if the retinal illumination is above the center of the retina, the rays will pass out in a downward direction, cross at the anterior focal point, and their position is now reversed as stated above. Therefore, only the upper portion of the rays, after crossing, enter the examiner's eye. These latter rays have passed through the lower illuminated portion of the pupil (Fig. 20).

The Brilliancy of the Light in the Pupil.—The brilliancy of the central light area or image is dependent on several factors:

1. The brightness of the true illumination on the retina (pages 37, 38).

2. The distance of the mirror from the source of light and of the mirror from the patient, the light becoming brighter as this distance is lessened.

3. The proximity to the anterior focal point. When at this point, all the rays of light passing out of the patient's pupil are nearly focused into the examiner's eye, but this increase in brilliancy is somewhat counterbalanced by the fact that the light comes from a smaller portion of the true retinal illumination.

4. The degree to which the brightness of the impor-

tant central portion of the retinal illumination is diminished by the sight hole in the mirror.

When the surgeon is at the anterior focal point he receives light from a very small portion of the retinal illumination, but the farther he is from this point the larger the area of the retina which reflects light to his eye.

Degree and Rate of Movement. — Recalling the fact that the light rays were likened to a lever and the pupil to its fulcrum, if the external end of this lever is moved six inches, the internal end moves twice as far as when the external end is moved three inches. Now, if the same rate of movement is used in both cases, it will be seen that it must take twice as long in the first as it does in the second case; and, if the light area at the examiner's face in one condition is twice the size of that in another, it is easily understood that the retinal illumination must move twice as far in one case as in the other, and if moved at the same rate, it must take twice as much time; therefore, the central light area will take twice the time to move aross the pupil. The nearer the examiner's eye is to the anterior focal point of an eye, the smaller the area of light at the examiner's face, therefore, the easier it is to move this area across the eye, requiring less change of position of the illumination on the retina, and consequently less tilting of the mirror and correspondingly less time. The whole depends on the size of the light area at the examiner's face.

The rate of movement of the central light area in the pupil also depends on the rate of movement of the retinal illumination, the latter being influenced by—

1. The rate of movement of the mirror.

2. Differences in the distance of the light from the mirror, and the mirror from the eye.

3. The distance of the nodal points from the retina. This will be readily understood by likening the rays of light entering the eye to a lever and the nodal points to its fulcrum. It will then be seen that the shorter the external end extending from the nodal points to the apparent source of light, and the longer the internal portion of the lever between the nodal points and the retina, the more rapid will be the movement of the inner arm. The posterior end of the latter corresponds to the retinal illumination.

The Mathematical Point of Reversal. — This is never found in actual practice, but only in theory in an ideal or standard eye. The light reflected from the fundus of the patient's eye passes out and forms an area of light at the examiner's face. If this area is much larger than the examiner's pupil, only a certain amount of the light enters his pupil, and the portion of the patient's pupil through which these rays pass alone appears brightly illuminated. The remainder of the patient's pupil appears slightly darker. If all the rays of light reflected from the patient's fundus would focus at or pass into the observer's pupil, he would receive rays of light through every part of the patient's pupil which therefore would appear completely illuminated, and he would be at the practical point of reversal. If the examiner could dilate his pupil *ad libitum* so as to make it correspond to the area of light on his face, the patient's pupil would always appear fully illuminated. It is thus seen that whenever the observer's pupil receives all the rays of light, the observer is at the practical point of reversal. However, in this ideal mathematical condition under consideration, a perfect anterior focal point, or point of reversal coinciding with a pin-point

pupil, must be imagined. The secondary rays of light will necessarily cross one another at this perfect focus through this pin-point sized pupil, thus making the nodal point coincide with the location of the pupil and point of reversal. Mathematically, they all coincide; although in practice the pupil is the determining factor, the nodal points being located behind the plane of the pupil.

Experiments and Observations.—The author recommends the carrying out of the following experiments and observations, since they will aid in the proper understanding of the test:

1. Blacken an ordinary visiting card on one side, or take any smooth, black, glossy piece of paper, and holding a strong 20-diopter convex lens close in front of it, reflect light through the lens upon the card by means of a plane or concave mirror. By tilting or rotating the mirror, the movement of the light area (corresponding to the retinal illumination) on the card can be studied. The concave mirror must be at such a distance that the light will have focused, or crossed, before reaching the lens. It is possible to watch from the side, and not through the lens, the movement of the light area on the card. It is often advisable to have an assistant tilt the mirror. The examiner may also find it expedient to place his eye in the position of the card, behind the lens, while an assistant slightly tilts the mirror. In this way, the differences between the movement of the light with the plane and concave mirror may be easily noticed. On removing the lens, it will be interesting to note the position of the light image in each mirror as it is slowly tilted.

2. Take a black card with a small white spot in its center, 2 or 3 millimeters in diameter; hold it behind a

20-diopter convex lens, which represents the dioptric media of the eye, and notice the apparent movement, position, size, etc., of the image of this white spot through the lens, as the card is slowly moved up and down, or from side to side. This white spot represents the retinal illumination, and its movement up and down or from side to side represents the movement of the retinal illumination when the mirrors are tilted. If a perfect lens is used, the observer's eye may be placed at such a distance in front of it that all the rays of light passing through it from the white spot on the card will be focused in his eye. If he sees a large white image of the white spot or a portion of it filling the whole lens, he is located at the point of reversal, or the anterior focal point of the spot on the card. If he moves closer to the lens, he can study the conditions of emmetropia, hypermetropia, and of a low degree of myopia, where the anterior focal point is situated behind the examiner, the rays of light not having focused before reaching his eye. On the other hand, if he moves farther back, that of a higher degree of myopia is studied where the anterior focal point is situated between the card and the examiner, the rays of light having focused before reaching his eye. When either in front of or behind the anterior focal point, the examiner can move his eye about in different directions and still see the image of the white spot on the card. The farther his eye is removed from the anterior focal point, the greater the space through which he can move his eye and still see the light spot. The observer may cover all dark or shady portions of the lens and still see the image. But, if he covers that portion of the lens through which the light rays pass to form this image, he will hide it from view. The white

spot, instead of being circular, may be in the shape of an equilateral triangle, so that it will be easy for the observer to know whether he is looking at an upright or inverted image by noting the direction in which the apex of the triangle points.

The peripheral light ring seen in spherical aberration, having its direction or rate of movement different from the movement of the central light area, may be well studied with almost any strong convex lens. If a strong cylindrical lens is held in front of the sphere, the bar-like appearance of the round white spot may be studied as in astigmatism.

To demonstrate that the usually circular-shaped retinal illumination does not depend on the shape of the source of light, reflect light from a mirror through different shaped holes in a card held close in front of another, and note that the illumination on the second card is the same shape as the holes in the first card. The perfect retinal illumination would be a mere point of light. If the light is not focused soon enough, or too soon, to form a focus on the retina, diffusion circles will represent each point of light in the source. If astigmatism is present, the light will be more nearly focused in one chief meridian than in the opposite, making an elliptical and sometimes even a linear-shaped illumination. If the shape of opening in the light screen is changed, the area of illumination thrown by any kind of mirror held close to the source of light will be similarly changed. If the mirror be so far from the source of light that it receives light on every part of it, the illumination caused by its reflection will be the same shape as the mirror.

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CHAPTER III.

PRACTICAL APPLICATION OF THE TEST WITH THE PLANE MIRROR. — EMMETROPIA. — HYPERMETROPIA. — MYOPIA. — REGULAR ASTIGMATISM. — MIXED ASTIGMATISM. — IRREGULAR ASTIGMATISM. — POSITIVE ABERRATION. — NEGATIVE ABERRATION. — CONICAL CORNEA. — CONICAL ASTIGMATISM. — SCISSORS APPEARANCE. — ACCOMMODATION. — SUMMARY.

Practical Use of the Plane Mirror. — Having mastered and become thoroughly familiar with the principles of photoscopy as explained in the preceding chapters, the student is now ready to consider the practical application of the plane mirror. This method seems to be the simpler, and an understanding thereof necessary, before attempting the explanation or use of the concave mirror, for the following reasons:

1. It leads to confusion to study two methods at the same time.

2. It is easier to understand the principles of the test when the plane mirror is used.

3. The plane mirror is more often useful; it can practically be used to the exclusion of the concave mirror.

4. Except in some cases of myopia, the apparent source of light and the anterior focal point of the eye can be more nearly approximated by the plane than is possible with the concave mirror. This is always so

when near the anterior focal point and if the source of light is near the mirror. This is indeed a very important desideratum, because a brighter and smaller illumination on the retina is obtained; therefore, a more distinct anterior focal point.

A description of the most useful and common method of using the plane mirror can now be considered. Some consideration of the other methods in use will be given subsequently.

1. The room must be darkened.

2. The patient and examiner are to be seated facing each other at a distance of 1 or $\frac{1}{2}$ meter, with their eyes and the light on the same level. However, no arbitrary rule governs this distance between patient and observer. The examiner may choose the particular distance he prefers in each individual case.

3. The source of light should be on the side opposite, on the same level, and at a distance of 5 or 6 inches from the examiner's eye in use.

4. There should be a 5- or 10-millimeter opening in the light screen, opposite the brightest part of the flame, thus permitting the central part of the light to pass in front of the examiner's unused eye and the shade, and to fall upon the mirror held before the other eye.

5. The mirror should be held before the eye having the greatest visual acuity; if the visual acuity of the two eyes is equal, before the right, if the examiner is right-handed; before the left, if left-handed.

6. Correcting lenses should be worn if they improve the examiner's vision, which should be at least $\frac{6}{6}$ for good work. But the fact must be remembered that they reflect some of the rays of light which would otherwise enter his eye. The examiner need take no note of

FIG. 13.—Shows arrangement of patient, examiner, bracket, and author's screen on cover chimney shielding the examiner's eye.

his own accommodation as he is compelled to do in ophthalmoscopy.

7. A trial frame should be properly adjusted on the patient's face.

8. The trial lenses should be near the examiner, so that he can insert them in the trial frame without rising. (The writer has an assistant place the required lenses in the trial frame as directed.)

9. Usually the patient's accommodation should be overcome previous to the examination by the use of a reliable cycloplegic. Complete paralysis of the ciliary muscle, producing loss of the accommodation, with moderate dilatation of the pupil, would be the ideal condition, but all drugs now in use produce full dilatation.

10. The patient's accommodation being thoroughly relaxed, he should be requested to look not only directly, but constantly, at the examiner's brow just above the mirror, or at the dark edge of the mirror. In case a cycloplegic has not been used and the accommodation is active, the patient should look in a staring, absent-minded manner past the brow, just above the examiner's ear, into the distance. It is sometimes wise, in this latter method, to place slightly fogging lenses before the other eye,—*i. e.*, a sufficiently strong convex (+) or weak concave (—) spherical lens,—thereby blurring distant vision. If he looks directly at the light in the mirror the irritation sometimes causes an irresistible desire to close the eye, although this is the proper method by which to examine the macula, especially for the spherical correction. The degree of astigmatism can often be better told by having the patient look, during the examination of both chief meridians, in

such a direction that a bright reflection may be obtained from the optic nerve ending. However, this would not give the proper spherical correction. In case of an existing strabismus, when the squinting eye is under examination, the other eye should be covered; in fact, the writer places a black disc before the other eye in nearly all cases.

11. It is advisable to have a meter stick, marked in dioptric focal lengths, for determining the distance from the patient's eye, as well as marked in the equivalent diopters to obtain the proper strength of concave (—) spherical lens to be added to the dark-room correction, in allowing for working distance to obtain the distant correction.

12. The handle of the mirror should be held firmly, yet lightly; the mirror should reflect the central, brightest rays of light into the patient's eye. It takes both patience and practice to do this, or even to keep the light on the face. The beginner is often at a loss to know where the reflected light is, but if he directs it on the unused hand held between the mirror and the patient's face, upon withdrawal of the hand the light will be seen on the patient's face. Proficiency in the control of the mirror will soon be acquired. Each one learns by practice the most convenient method of holding and manipulating the mirror, possibly no two having exactly the same method.

13. The next step is to tilt slightly or rotate the mirror about an axis corresponding to one of its meridians. Unless these movements are limited in range, the light will be lost from the eye. The rate of movement desired, whether slow or fast, will be acquired in actual practice. Generally it is best to move the mirror slowly,

thus having an opportunity to study the conditions. The examiner should be certain of every change in the pupil, particularly in its central area, especially when near the anterior focal point, or if spheric aberration is present. The writer has observed many moving the light up and down the face so fast that no mortal could possibly tell in which direction the light was moving at any one particular time, or even recognize anything else of importance.

14. The observer will next study the light in the pupil. This will vary under different conditions as follows:

(*a*) Personal differences, due chiefly to varying degrees of pigmentation of the eye ground. In brunettes and mulattoes it is quite unlike that in blondes and albinos.

(*b*) The patient may turn the eye so that the light will be reflected from different parts. The light coming from the nerve head, or an area of retained nerve fibers, is quite different from that emanating from a dark spot or a collection of pigment in the retina.

(*c*) It will vary in eyes of different refractive strengths; and, of course, it will be altered by changes in the lenses before the eye.

(*d*) It will be different as the conditions change under which the examination progresses,—*e. g.*, the degree of darkness in the room, the relative position of the examiner and patient, the changes in the quality and quantity of the light, the distance between the mirror and the light, between the mirror and the eye, etc.

As a rule, however, a red or orange-colored glare or glow fills the pupil, but the following conditions must be carefully noted and as far as possible avoided, as otherwise great confusion may result:

1. Very small catoptric images of the light or other objects reflected by the surfaces of the cornea and lens can always be seen.

2. Images of the light, of other objects, and even of the examiner's face reflected by the surfaces of the trial lens before the eye.

3. A small, dark area due to the perforation in the mirror and more noticeable under certain conditions than others.

4. Frequently the outer portion of the red glare presents a bright ring of light, due to the fact that the periphery of the lens, or cornea, is often of quite a different refractive strength from the center, and the rays of light passing through the periphery have focused at the examiner's eye, while those through the center have not. However, the examiner is concerned only with the central portion of light. This peripheral light, due to spherical aberration, will vary in width and brightness as the distance between the examiner and patient is changed, or different lenses placed before the eye. It is the source of more error, and takes more patience and practice to avoid than anything else in the test. (Frontispiece 2 and 3).

5. Sometimes an image of a hyaloid artery, another vessel or vessels, masses of connective tissue sometimes even in the vitreous, or the nerve ending, may be seen. All these may be avoided by having the patient look in a slightly different direction from that in which these conditions were observed.

6. Often a very bright reflex is caused by an improperly placed test lens; this can be avoided by changing the position of the lens.

The important thing is a round, elliptical, or linear-

shaped area, or image of light, apparently moving in the central part of the pupil as the mirror is tilted. Rarely it presents a smoky, and not the characteristic light appearance. It is necessarily small and moves slowly when the examiner is far from the anterior focal point of the eye, but becomes larger, more brilliant, and moves faster as he approaches it, and completely fills the pupil when he is at the anterior focal point. Success depends on noticing the size, shape, brilliancy, direction, and rate of movement of the central light area. Except when the examiner is situated at the anterior focal point, this central light area is always surrounded by a darker portion which attends it in all its movements, and were it not for the contrast or boundary between these two areas, the movements of the light area could not be recognized.

A convex (+) spherical lens is required when the central light area, or image, moves in the same direction as the light on the face, and indicates that the anterior focal point is situated behind the examiner—that the rays of light have not focused before reaching his eye—as in hypermetropia, emmetropia, or a low degree of myopia. A concave (—) spherical lens is needed when the central light image moves in an opposite direction to the light on the face, and indicates that the anterior focal point is situated between the patient and examiner, in front of the latter, as in a higher degree of myopia. If the light area, or image, moves faster in one meridian than in another, or is shaped like a bar of light, it indicates astigmatism, and a cylinder is required in addition.

Emmetropia.—As before stated, rays of light passing from an emmetropic eye are for all practical purposes parallel, forming a cylinder outside the eye. One end

of this cylinder rests in the pupil, the other end at infinity. When the plane mirror is tilted, the light on the face and in the pupil moves in the same direction. This at once shows that a plus lens in needed. If a +.88 s. lens be placed before the eye, the central light area is larger, brighter, moves faster, and in the same direction as before; but if a +1.12 s. lens be used, the same phenomena are observed, except that the light in the pupil moves in the opposite direction to the light on the

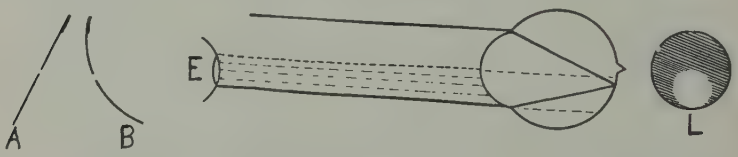

FIG. 14.—Emmetropia with the plane mirror tilted downward and the concave upward. A, plane mirror. B, concave mirror. The heavy black part above represents that portion of the mirror from which light is reflected to the patient's eyes. The retinal illumination is seen to be below the center of the retina. The heavy black lines give the boundary of the light passing out of the patient's pupil in an upward direction. Only the lower rays at the examiner's face pass into his pupil, E, and if traced back to the patient's pupil by the dotted lines are seen to come through the lower part of it. This lower part of the pupil appears brightly illuminated by the central image, which is projected between the two dotted lines within the eye. The pupil appears diagrammatically as in L. The image is erect as the rays forming it do not cross in passing to the examiner's eye. A convex +1.00 s. lens placed before such an eye would cause all the rays of light emerging from the eye to focus into the examiner's pupil E, and make the patient's pupil appear full of light (Fig. 16.)

face. Therefore, in the first case the examiner was within, in the second, beyond, the anterior focal point. The lens whose strength is midway between the two will focus the rays of light at the examiner's eye. It is a good plan in practice to use two lenses, one producing a focus just beyond, the other just before reaching, the examiner's eye. It is better to select the lens whose strength is midway between these two, as the final result, rather than attempt to find one lens which

will focus the rays of light exactly at the examiner's eye; for it is sometimes very difficult to be certain when at the anterior focal point, but usually easy to know when beyond or within it.

In the above example, if the examiner is working at one meter distance, a +1.00 s. lens would be the final result for that distance, and by adding a —1.00 s. lens as the allowance for working distance (see pp. 87, 88 89), the +1.00 s. would be neutralized and no lens would be necessary for the distance.

If the examiner should place a lens in front of the

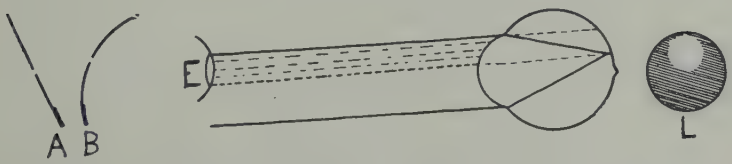

FIG. 15. — Emmetropia with the plane mirror tilted upward and the concave downward. A, plane mirror. B, concave mirror. The retinal illumination is seen to be above the center of the retina. The heavy black lines give the boundary of the light passing out of the patient's pupil in a downward direction. Only the upper rays of the area of light at the examiner's face pass into the examiner's pupil E, and if traced back to the patient's pupil by the dotted lines are seen to pass through the upper part of it. This upper part of the pupil appears brightly illuminated by the image which is projected between the two dotted lines within the eye. The pupil appears diagrammatically as in L. The image is erect because the rays forming it do not cross in passing to the observer's eye.

patient's eye that focuses the rays of light at his own eye, no movement of the central light area being noticeable, by first moving forward and then backward, the difference in direction in which the light moves in each position determines whether he is within or without the focal point. The focal point is between these two positions. When the examiner moves backward, the central light area, or image, will move in an opposite direction to the light on the face, and when he moves

forward, it will move in the same direction as the light on the face (Figs. 14, 15, and 16).

Particular attention should be given to the central light area, and as far as possible the confusing peripheral light areas due to aberration should be avoided. (See Positive and Negative Aberration, pp. 73, 75.)

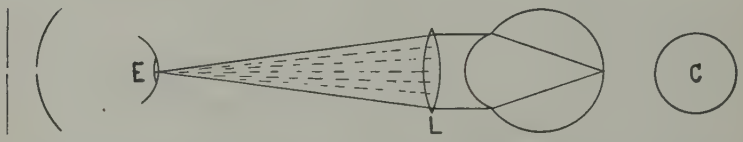

FIG. 16. — The examiner's eye at the anterior focal point of an eye: Emmetropia, hypermetropia, or a low degree of myopia with the correcting convex spherical lens before the eye. The rays of light passing from the retinal illumination out of the observed pupil are focused by the lens L into the examiner's pupil E, as seen by the dotted lines, and therefore the observed pupil appears to be filled with light (a magnified image of all or part of the retinal illumination) as represented diagrammatically in C. No image of the darker portion of the retina is formed in an eye which has equal refractive strength through all parts of its pupil since all the rays will then focus in the examiner's pupil which otherwise they will not do.

If a concave (—) replaced the convex (+) lens in this diagram before an eye having a high degree of myopia focusing all the rays of light passing from the retinal illumination into the examiner's pupil E, it would represent diagrammatically the examiner at the anterior focal point of a more myopic eye.

This diagram also represents the examiner's eye at the anterior focal point of the vertical meridian (ax. 90) of an eye.

Hypermetropia.—In examining a hypermetropic eye by this method, it is necessary to remember that the light rays passing out of such an eye form a truncated cone (Fig. 8[3]), its smaller end filling the pupil, the larger end resting at infinity, or, for practical purposes, at the examiner's face.

The size of the larger end of this cone at the examiner's face depends on the distance of the examiner and the amount of hypermetropia present, and chiefly determines the size, shape, brilliancy, and rate of movement of the central light area in the patient's pupil.

The central light area moves in the same direction as the light on the face; therefore, a convex (+) lens is needed. The same procedure now is followed as first described in

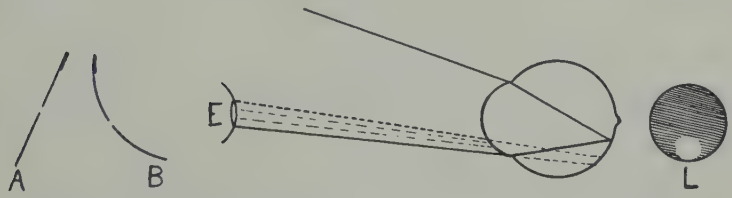

FIG. 17.— Hypermetropia with the plane mirror tilted downward and the concave upward. A, plane mirror. B, concave. The retinal illumination is seen to be below the center of the retina. The heavy black lines give the boundary of the light passing out of the patient's pupil in an upward direction. Only the lower rays at the examiner's face pass into his pupil E, and if traced back to the patient's pupil by the dotted lines are seen to come through the lower part of it. This lower part of the pupil appears brightly illuminated by the image, which is projected between the two dotted lines within the eye. The pupil appears diagrammatically as in L. The image is erect since the rays do not cross in passing to the examiner's eye.

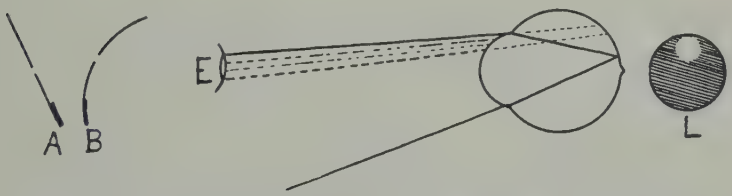

FIG. 18.—Hypermetropia with the plane mirror tilted upward and the concave downward. A, plane mirror. B, concave mirror. The heavy black part below represents that portion of the mirror from which the light is reflected to the patient's eye. The retinal illumination is seen to be above the center of the retina. The heavy black lines give the boundary of the light passing out of the patient's pupil in a downward direction. Only the upper rays of the area of light at the examiner's face pass into the examiner's pupil E, and if traced back to the patient's pupil by the dotted lines are seen to come through the upper part of it. This upper part of the pupil appears brightly illuminated by the image which is projected between the two dotted lines within the eye. The pupil appears diagrammatically as in L. The image is erect because the rays forming it do not cross in passing to the observer's eye.

emmetropia. Two lenses are selected, each producing a light area in the pupil of the same size, shape, bril-

liancy, and rate of movement, except that in one the central light area in the pupil moves with, and with the other against, the light on the face. The lens whose strength is midway between the two used will be the final result. If the size, shape, brilliancy, and rate of movement with a +1.75 s. placed before the eye is the same as with a +2.25 s., but with the +1.75 s. the central light in the pupil moves with, and with the +2.25 s. against, the light on the face, a +2.00 s. lens will be the final result for 1 meter; and, by adding a —1.00 s. as the allowance for working distance, the +1.00 s. that remains is the result for the distance. The examiner, by moving within and without the anterior focal point just referred to—*i. e.*, closer to, or farther from, the patient than this point—can locate its exact position and is thus enabled to determine the correction for distance (Figs. 17 and 18).

Myopia (Hypometropia).—Rays of light returning from the retina of a myopic eye pass out and form a cone whose apex is at the anterior focal point and whose base corresponds to the pupil of the eye (Fig. 8[2]). If nothing obstructs the light at its anterior focal point the rays will cross and pass on, forming another cone, its apex touching the apex of the first cone, its base at infinity. Two cones are thus formed. The examiner's eye will either be at the apex (anterior focal point) or in one of the cones. If at the apex (the anterior focal point of the eye) the examiner will have all the signs to indicate it,—viz., the pupil filled by central light area, not movable, etc. If in the first cone, or closer to the eye than its anterior focal point, the same signs will be present as in emmetropia and hypermetropia,—*i. e.*,

light moving with the light on the face, and convex (+) spherical lenses should be used until the focal point and the examiner's eye coincide. By adding a —1.00 s. to the result, if working at one meter, the correction for distance will be obtained. If the examiner is beyond the anterior focal point, and thus in the second cone, the central light area in the pupil will move opposite to the light on the face, and concave (—) spherical lenses will be needed. Pursuing the same method as in the former

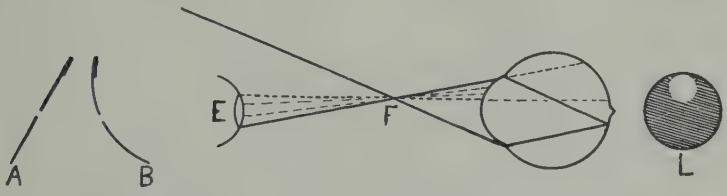

FIG. 19.—Myopia with the plane mirror tilted downward and the concave upward. A, plane mirror. B, concave mirror. The retinal illumination is seen to be below the center of the retina. The heavy black lines give the boundary of the light passing out of the patient's pupil in an upward direction. The light rays are seen to focus and cross at F; only the lower rays at the examiner's face pass into his pupil E, and if traced back to the patient's pupil by the dotted lines are seen to come through the upper part of it, having crossed at F. This upper part of the pupil appears brightly illuminated by the image which is projected between the two dotted lines within the eye. The pupil appears diagrammatically as in L. The image is inverted, the rays forming it having crossed in passing to the examiner's eye.

conditions already considered, two lenses are selected, one producing a focus of the light just beyond, the other just before reaching the examiner's eye. Therefore, to produce a focus at the examiner's eye, it is necessary to select a lens whose strength is midway between the two. To find the correction for distance, a —1.00 s. must be added if working at one meter distance,—*e. g.*, if —2.00 s. be the correction for one meter adding —1.00 s., the result, —3.00 s., is the correction for distance. It is also possible to find the location of the anterior

focal point by moving closer to, or farther from, the patient's eye, and thus determine the degree of myopia present (Figs. 19 and 20).

Regular Astigmatism.—In regular astigmatism the rays of light form neither a cylinder nor a perfect or truncated cone outside the eye, because rays passing through one chief meridian will focus at a greater or less distance from the eye than those passing through the meridian at right angles. Those through one me-

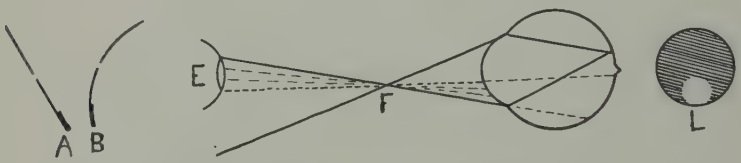

FIG. 20.—Myopia with the plane mirror tilted upward and the concave downward. A, plane mirror. B, concave mirror. The heavy black part below represents that portion of the mirror from which the light is reflected to the patient's eye. The retinal illumination is seen to be above the center of the retina. The heavy black lines give the boundary of the light passing out of the patient's pupil in a downward direction. The light rays are seen to focus and cross at F. Only the upper rays at the examiner's face pass into his pupil E, and if traced back to the patient's pupil by the dotted lines, are seen to come through the lower part of it, having crossed at F. This lower part of the pupil appears brightly illuminated by the image which is projected between the two dotted lines within the eye. The pupil appears diagrammatically as in L. The image is inverted, the rays forming it having crossed in passing to the examiner's eye.

ridian will be more or less divergent, or convergent, than those through the opposite. In other words, the refractive power of one of the two chief meridians is stronger, or weaker, than that of the opposite meridian. In this form of astigmatism the examiner is concerned in determining the position of the anterior focal point in only the strongest and weakest meridians. It is therefore necessary to determine in which direction each meridian lies. The meridian whose anterior focal point is nearest the examiner's eye will appear more nearly full

of light than the opposite, because the examiner's eye receives more of the rays of light which pass through that meridian than through the other. The central light area has more or less the appearance of a bar, and the more nearly it fills a meridian, the nearer the examiner's eye is to the anterior focal point of that meridian. In other words, the length of the bar lies in the more nearly corrected meridian, and the direction of its movement endways determines whether a convex (+) or a concave (−) spherical lens is needed. When the anterior focal point of a meridian and the examiner's eye coincide, the bar of light extends entirely across the pupil in that meridian. If in such a case the degree of astigmatism is low, the width of the bar of light will be much greater than if it is high; for in a low degree of astigmatism the anterior focal points of the two principal meridians are not widely separated; the examiner's eye receives all the rays of light from the meridian corresponding to the length of the bar, and nearly all from the one corresponding to the width. In a high degree of astigmatism, the anterior focal points are widely separated, and the examiner's eye, while receiving the rays of light from one meridian, receives only a small number of the rays from the opposite meridian. It will be seen that the degree of astigmatism is the difference between the refractive strengths of the two chief meridians, or it is the difference between the distances of their two anterior focal points from the eye expressed in focal lengths. In other words, it is the strength of the lens which will move either anterior focal point to the other. This can be done by a plus lens, which will shorten the distance of the farther focal point, or by a minus lens, which will ex-

tend the distance of the nearer one, until the two coincide. The bar of light is always seen in one of the chief meridians, and the mirror should be tilted so that the light moves in or along this meridian (up and down if at axis 90, from side to side if at axis 180). This meridian should be corrected before proceeding to the correction of the opposite, because it is better in practice to correct each meridian separately, using the methods already described under myopia and hypermetropia (Fig. 21 and Frontispiece 4, 5, and 6).

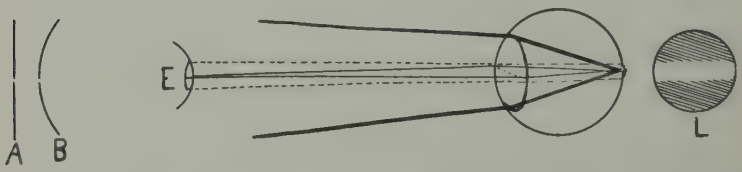

FIG. 21.—Regular astigmatism. A, plane mirror. B, concave mirror. The heavy black lines indicate the boundary of the rays passing out of the pupil through the vertical meridian (ax. 90°). Only that portion of these rays included between the two dotted lines enter the examiner's pupil E. The fine black lines represent the rays passing out of the pupil through the horizontal meridian (ax. 180°), and they are seen to focus in the examiner's pupil E. Since all the rays passing out of the pupil of the eye in the horizontal meridian, but only the central ones in the vertical meridian, enter the examiner's eye, the horizontal meridian of the pupil appears full of light, but only the central part of the vertical meridian. This gives rise to the bar-like appearance across the pupil as seen in L. The dotted lines within the eye give the position of the image of light as it is projected within the eye in the vertical meridian.

The examiner must remember that he is always refracting the meridian in the direction in which or along which he moves the mirror (this is not ophthalmoscopy). He should move the mirror so that the light will move along in the direction of the bar of light, thus making the bar of light move endways until it ceases to move, or extends completely throughout the meridian in which it lies. It is wise to find a lens with which it moves slightly with, then another with which it moves slightly

against, the light on the face. The lens in strength between these two will correct that meridian.

Thus, if in a given case with a +.75 s. the light moves with, and with a +1.25 s. against, in the vertical meridian (axis 90°), the correction for that meridian would be a +1.00 s. The bar of light will now extend entirely across the pupil in that meridian. By the same method, the correction for the opposite horizontal meridian may be found to be a +2.00 s., causing the bar of light to extend across the pupil in that meridian. The amount of astigmatism is equal to the difference in strength between the two lenses necessary for the correction of each meridian, which is +1.00 c. The correction for one meter distance will be +1.00 s. ⌒ + 1.00 c. axis 90°. The distant correction needed would be +1.00 c. axis 90°. (See General Considerations.)

The great majority of eyes having astigmatism also require some spherical correction. In such cases it is necessary to place convex (+) or concave (—) spheres before the eyes until the examiner is close to the anterior focal point of one of the meridians, when the bar of light will be more clearly seen extending in that meridian. It is sometimes best in correcting high degrees of astigmatism to use a sphere and a cylinder in combination, the sphere correcting one, and the two combined the opposite meridian. A sphere is found which corrects one meridian—*e. g.*, axis 90°—then different cylinders are placed at the same axis (90)—since the strength of a cylinder is at right angles to its axis—until the opposite meridian is likewise corrected. Many do this as a routine practice, but it takes much time and great care to place cylinders at the right axes, especially in a dark room. Except in certain cases, the writer

much prefers to correct each meridian separately with a sphere. It is often advisable to prove the result with the sphero-cylinder combination, making the anterior focal points of both principal meridians coincide in position with the examiner's eye.

Experience frequently enables the examiner to determine the degree of astigmatism present by observing the rate of movement of the light area in one of the principal meridians after the other is corrected by a sphere—if slow, a strong, if fast, a weak cylinder is required—and also by observing the characteristics of the bar of light. Cases with a low degree of astigmatism may often be detected by a faint shaded area on each side of the bar of light (Frontispiece 6), and also by noting with the correct sphere (or one slightly too strong or too weak) if there is any movement in one of the meridians while the opposite meridian appears corrected, or if the movement is more distinct in one than in the other meridian. Great care must be exercised in these cases, and, when in doubt, it is often advisable to increase or decrease the correcting sphere, as it is usually possible with one or the other to notice a more distinct movement in one of the chief meridians than in the opposite meridian.

If there is a high degree of astigmatism, in a case requiring only a weak sphere to correct one meridian, the bar of light will be recognized on first inspection of the reflex; but, if the astigmatism is low in degree and a strong sphere is required for the high degree of hypermetropia or myopia present, the bar of light will not be recognized until a strong sphere corrects, or nearly corrects, one of the meridians.

As pointed out by my brother, Dr. David W. Steven-

son, of Richmond, Indiana, astigmatism is caused entirely by the anterior refractive surfaces and media. Theoretically, in order to determine the proper sphere, the illuminated area on the patient's retina should lie on its central, most important part, the macula, the patient being directed to look at the light image in the mirror. This portion of the retina is usually dark and reflects the light poorly to the examiner's eye. During the examination for astigmatism, if the patient looks steadily in such a direction that the light will be reflected by a certain part of the bright optic nerve ending, it is sometimes easier to determine the degree of astigmatism on account of the brighter illumination. If the illuminated area at the back of the eye remains in the same location and the proper sphere is determined to correct each of the two chief meridians, the difference in strength between the correcting spheres for the two meridians will be equal to the degree of astigmatism. In order to determine the proper spherical correction, the illumination on the retina should be at the macula, but the optic nerve ending or any other bright part of the fundus may be used in determining the degree of astigmatism, which depends merely upon the difference in curvature of the two chief meridians of the anterior refractive surfaces.

If the light from the mirror is not moved along one of the principal meridians, when astigmatism is present the bar of light seems to move in a direction different from that in which it really does move. This may be explained by passing a card, the edge of which is held at an angle of 45°, horizontally across and behind a small round opening in a larger card. The edge of the card will appear to be moving in a slanting direc-

tion instead of horizontally. So if a slanting bar of light is moved horizontally across the pupil, or up and down, it will appear to be moving in a slanting direction at right angles to its length instead of in the direction in which it is really moved.

Mixed Astigmatism.—This being a form of regular astigmatism it is dealt with in an exactly similar manner. One of the chief meridians is first corrected by a sphere, the light being moved along that meridian; then the sphere is found that corrects the meridian at right angles. The results should be properly recorded on the cross (Fig. 21 and Frontispiece 4, 5, and 6).

Irregular Astigmatism.—In an ideal standard, a so-called emmetropic or a typical hypermetropic or myopic eye, all the areas of the pupil will have exactly the same refractive strength, and all meridians will have exactly the same strength. Likewise every part of each meridian will be alike. In practice such eyes are never found. Every eye has either slight or marked differences in the refractive strength in its different pupillary areas. This is due to irregularities, first, in the surfaces; second, to differences in the density of the different portions of one or more of its media. The difference in the refractive strength of the different areas of the lens is due to irregularities of its surfaces, and partly to the fact that the individual lens fibers are not alike in shape, arrangement, or density. The slight differences, which always exist, give rise to the appearance of radiations passing from the edge of stars, or distant lights; but changes in the lens occurring during the formation of cataract, sometimes congenital, are gross enough to cause much annoyance. Usually these spicules, or lens opacities, which are seen

as shadows or dark lines, extend from the periphery toward the center (Frontispiece 11). So long as they do not encroach on the pupillary area (which changes as the degree of light and accommodation varies, causing contraction or dilatation of the pupil), they do not interfere with vision. Often they cannot be recognized with the opthalmoscope, and not even with the photoscope, unless the pupil is dilated and the observer is near the anterior focal point. The early recognition of these changes is important from the prognostic and prophylactic standpoints, indicating local or general treatment, a change of occupation, eye rest, or the use of proper lenses, especially if there is astigmatism against the rule, or at an oblique axis (Frontispiece 11 and 12).

The cornea ought to have both surfaces curved so regularly that every part of each meridian would have the same curvature, and that every meridian would be like every other meridian. If two meridians at right angles have not the same degree of curvature, and all meridians in between them gradually equalize the difference, then there is regular astigmatism. But when there are surface irregularities, differences in the curvature of different parts of one meridian, so that one area focuses at one place, and another bearing a particular relationship to this one focuses at another place, there is irregular astigmatism.

Distinct areas of light and of darkness will be noticed, especially upon approaching the anterior focal point. The reason for this is that the rays passing through the light areas enter the observer's eye, but those through the dark areas do not.

The same methods should be used in the examination and correction of these cases as have been described for

those already considered. However, the examiner should be careful to confine his attention as much as possible to the central portion (easy to say, but difficult to do) which corresponds to the normal pupil, observing at all times the movement of the central light only, avoiding the smaller confusing areas of light and darkness. Often, to obtain the best results, these cases should be examined not only before and during the influence of a cycloplegic but also afterward by subjective methods. (The axes of corneal and lenticular astigmatism do not always lie in the same meridian nor at right angles to each other. This condition might well be termed crossed astigmatism and is probably more frequent than generally supposed because of difficulty of detection. Certain other atypical types of astigmatism due, *e. g.*, to a combination of corneal astigmatism with lenticular inclination, may also be termed crossed astigmatism.)

Positive Aberration.—This is a condition in which rays of light passing through the periphery of each meridian of a spherical refractive medium focus nearer it than those passing through its center. This is due to the fact that the peripheral has greater refractive strength than the central portion. This condition is the most frequent cause of the annoyances in photoscopy. The examiner is interested only in finding the correction of the central area, and not that of the periphery, for when the pupil contracts after the effects of the cycloplegic have disappeared the central area only is used. When the examiner is within the anterior focal points of both the central and peripheral portions of a given meridian, both the central and peripheral light in the pupil will move in the same direction as the light on

the face; but, as the examiner comes nearer the focus of the peripheral than of the central rays, the peripheral band of light will appear more brilliant and move faster than the central area. A convex (+) spherical lens is needed, and, if a convex lens is already before the eye, a stronger one; but a weaker one if a concave has been used.

When the examiner is between the focal points of the central and peripheral rays, the peripheral band of

FIG. 22.—Positive aberration. The peripheral rays of light passing through this lens are seen to focus at A, before those passing through the more central part, which focus at B. If the examiner's pupil were located at A, the whole periphery would be occupied with a band of light, whereas the more central area would be occupied by a dimmer central image moving with the light on the face (with a plane mirror). If the examiner's eye were located at B, the central part of the pupil would be brightly illuminated and there would be a band of light in the peripheral area moving against the light on the face (with the plane mirror). If the examiner were located midway between A and B, there would be a peripheral and central area of light moving at the same rate in opposite directions (with plane or concave mirrors). If the examiner be located beyond B, both central and peripheral areas of light would move against the light on the face, but the central area would move more rapidly (with the plane mirror). If the examiner's eye be located closer to the lens than A, both central and peripheral areas would move with the light on the face, but the peripheral area would move faster and be more brightly illuminated (with the plane mirror).

light will move against the light on the face, while the central area will still move with the light on the face. The peripheral band of light and the central light area are apt to encroach upon each other, and their relative brilliancy and rate of movement depend on the position of the examiner's eye between their focusing points. The pupil may appear full of light, and this often leads the examiner to think wrongly he is at the anterior focal point; the peripheral light moving

against may lead him to believe wrongly he is beyond the anterior focal point, and thus in need of a concave (—) spherical lens; or, if a lens is already before the eye, a weaker if convex, and a stronger if concave.

This confusing appearance is the most frequent source of error with which the photoscopist has to contend. In order to overcome this annoyance, he should ignore the peripheral and confine the attention entirely to the central light area, which will be seen to move with the light on the face (this, however, is difficult and sometimes almost impossible to do). A convex (+) spherical lens is needed, and if a lens is already before the eye, a stronger convex, if a convex; and a weaker concave, if a concave.

When the examiner is beyond both focal points, the peripheral band and central light areas move against the light on the face, the central being more brilliant and moving faster than the peripheral. For this, a concave (—) spherical lens is required. If a lens is already before the eye, a weaker if convex, and a stronger if concave (Frontispiece 2 and 3).

Photoscopy is of great value in these cases, especially when there is a high degree of aberration. In these, subjective examinations are sometimes misleading, as the patient with a dilated pupil may choose correcting lenses for the large peripheral and ignore the smaller, more important central portion of the pupil, thus choosing too weak convex or too strong concave lenses in positive aberration or the opposite in negative aberration. In determining how much to allow for the cycloplegic in the final correction, or whether to give the full correction or not, the writer always considers the degree and nature of the aberration present.

Negative Aberration.—This is a condition in which rays of light passing through the periphery of each meridian of a spherical refractive medium focus farther from it than those passing through its center. This is due to the fact that the peripheral has less refractive strength than the central portion. This condition is exactly the reverse of positive aberration. When the examiner is within, between, or beyond the anterior focal points, exactly the reverse will be observed from that which was noted in positive aberration (Fig. 23).

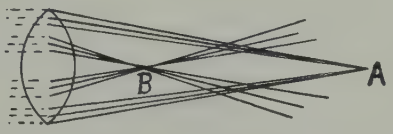

FIG. 23.—Negative aberration. The central rays of light focus at B, the peripheral at A. If the examiner be located at B, the central area will be filled with light and the peripheral area will be occupied by a band of light moving with the light on the face (plane mirror). If at A, the peripheral area will be occupied by a bright band of light, the central by a dimmer area of light moving against the light on the face (plane mirror). If midway between A and B, the peripheral area of light will move with the light on the face at the same rate that the central will move against the light on the face. If beyond A, both areas will move against the light on the face, but at a different rate, the peripheral moving faster and being brighter. If within B, both will move with the light on the face, the central being brighter and moving faster.

Conical Cornea.—With a conical cornea there is a marked negative aberration in which the degree of myopia in the center of the pupil is high, while that of the periphery is very much lower; or, perchance, this portion may even be hypermetropic. The focusing point of the peripheral rays is much farther removed from the eye than that of the central. If the peripheral rays focus near the examiner's eye, a large, brilliant, rapidly moving light will be seen in the periphery which, toward the center, becomes smaller, less bril-

liant, and moves more slowly. This triangular shaped area of light, which is brilliant at its base and dim at its apex, moves rapidly around the center of the cornea as on a pivot. It must be remembered, however, that the apex of the cone is not always central, and that under such conditions astigmatism is nearly always present. The observer should try to determine the proper lens or lenses for only the central area, and avoid the peripheral ones as much as possible. In addition, a careful subjective examination should be made in these cases after the pupil has regained its normal size (Frontispiece 7 and 8).

Conical Astigmatism.—R. D. Batten (*Ophthalmic Review*, January, 1897) called attention to the phenomenon that a bar of light while moving across the pupil sometimes changes its direction or axis as if swinging around the apex of a cone beyond the margin of the cornea. The direction of the bar should be noticed when it is at the center of the pupil.

Scissors Appearance.—If one-half, or more, of the refractive media in the pupillary area is stronger, or weaker, than the remaining portion, it will be readily understood that the rays passing through one portion, or half of the pupil, will be more or less convergent or divergent than those passing through the other sections. One-half, or more, of each meridian is stronger, or weaker, than the opposite portion of the same meridian. If myopia is present in both portions, or is produced by the aid of lenses, the anterior focal point for each half or portion will be at a different distance in front of the eye.

When beyond both, but near the farther anterior focal point, the central light in each half will move at a

different rate in a similar direction against the light on the face. This is also true if within both anterior focal points, but now they move with the light on the face. If between the two, the movement for each half will be opposite. Generally there is considerable regular

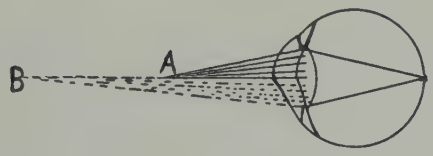

FIG. 24.—Scissors movement. The refractive power of the upper part of the dioptric media is stronger than that of the lower, because of the difference in curvature of the upper and lower part of the cornea and lens. The rays passing through the upper part focus at A, and cross at this point. Those passing through the lower part focus at B. If the examiner's eye be located between A and B, he would see an area in the upper part moving against, and one in the lower part of the pupil moving with the light on the face (with the plane mirror). The two areas move in opposite directions.

astigmatism associated with this condition; if so, two bars of light will be seen moving toward or away from each other, like the blades of a pair of scissors, provided the examiner is between the two focal points. If

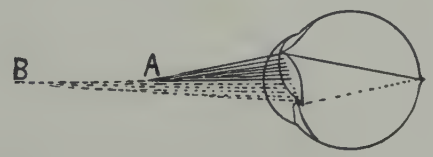

FIG. 25.—Scissors movement. This represents a case where the rays passing through the upper part of the lens focus before those passing through the lower part, because of the inclination of the lens. (See explanation of Fig. 24.)

one of these bars lies in the visual zone, that portion should be corrected and the other ignored. If, however, the visual zone lies between the two bars, a correction should be sought in which the size, shape, brilliancy, and

rate of movement of the two are the same, while the direction of their movement is opposite. The difference between the two portions is thus equalized, and the result is the correction for the intermediate visual zone.

The scissors appearance is no doubt generally due to the tilting of the lens or obliquity of one or more of the dioptric surfaces. It can be produced in an ordinary lens by holding it obliquely, or looking into an eye from a direction at a considerable angle to the optic axis. It has been suggested by Dr. James Thorington that reading in the recumbent position might possibly produce it. No doubt it is sometimes congenital. It is not infrequent after an operation on the cornea.

Accommodation.—If paralysis or spasm of accommodation or imperfect cycloplegia after the use of cycloplegics is suspected, the amount of accommodative power, if any be present, may be readily determined. It is only necessary to find the correcting lens for the eye when looking, first, at some distant object; second, at an object held close before the eye when the eyes should strongly converge. The difference, if any, between the refractive strengths of the two lenses gives the result. It may also be determined by subtracting the strength of the correcting lens for distance from the strength of the lens for near, found by the surgeon in dioptric focal lengths by approaching the observed eye until located at its anterior focal point for near.

Summary.—While working at a distance of one meter from the patient with a plane mirror, the following facts will hold true:

1. In hypermetropia the central light will move with the light on the face; all meridians will be alike. A convex (+) spherical lens is needed for the correction.

2. In emmetropia the same is found as in hypermetropia.

3. In myopia of less than one diopter, again the same is true as in hypermetropia.

4. In myopia of more than one diopter, the central light will move against the light on the face, and the same in all meridians; a concave (—) spherical lens is needed for this correction.

5. In regular astigmatism the two chief meridians which are at right angles to each other are not of the same strength. Each of these two chief meridians is corrected separately in the same manner as is done in cases of simple hypermetropia, emmetropia, or myopia.

6. In irregular astigmatism different parts of the same meridian, bearing a definite relationship to one another, have different refractive strengths. The irregularity should be avoided as much as possible, and the same method used as in the conditions mentioned above.

7. In positive aberration the peripheral part of each individual meridian has the same refractive strength as the diametrically opposite part, but is stronger than the central portion of this same meridian.

8. In negative aberration the peripheral part of each individual meridian has the same refractive strength as the diametrically opposite part, but is weaker than the central portion of this same meridian.

9. In conical cornea a condition of exaggerated negative aberration is found. The rays that pass through the apex of the cone focus before those passing through the periphery.

10. In scissors appearance two bars of light in the

pupil approach and recede from one another like the blades of a pair of scissors, because of the fact that the rays of light through one-half or part of the pupil focus sooner than those passing through the opposite half or part.

CHAPTER IV.

GENERAL CONSIDERATIONS.—CYCLOPLEGICS.—CONCAVE MIRROR.—AIDS TO ACCURACY.—AUTOPHOTOSCOPY.—RELATIVE ADVANTAGES OF PLANE AND CONCAVE MIRRORS.

General Considerations.—The best method of keeping a record of a photoscopic examination is what may be termed "putting it on the cross." When the location of the anterior focal point of the meridian in which the light is moved has been found and the strength and denomination of the lens determined, it is written at the end of a line which is drawn on paper in a direction corresponding to the meridian. The light is next moved across the eye in the direction of the opposite meridian, and the strength and sign of the lens required for this is written at the end of a line drawn at right angles to the other line,—*e. g.*, after the anterior focal point in the vertical meridian, axis 90, is found, by moving the light up and down, a record is made by drawing a vertical line (*a b*, Fig. 26) and writing the strength and sign of the spherical lens which, in this example, is assumed to be a +2.00 s., at the end of the line.

A record of the strength of the horizontal meridian, found by moving the light from side to side, should be made in the same manner at the end of a horizontal line (*c d*), and the strength of the lens required may be assumed to be a +2.00 s. also.

In the various forms of astigmatism one of the two

chief meridians must first be determined, as it may lie in any direction,—*i. e.*, at any axis. The other chief meridian is nearly always at right angles to this one. The bar of light is always seen in one of the principal meridians. For example, if in a given case one of the chief meridians, the correction of which is a +2.50 s., is found to lie at axis 45°, a line (*a b*, Fig. 27) should be drawn in this same direction, and the strength and sign marked at the end of this line. If the correction of the meridian at right angles is a +3.00 s., it should be recorded at the end of its line *c d*, which is at right angles to the line *a b*.

Writing the prescription equivalent for the result on

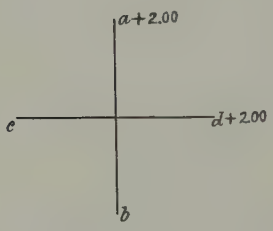

FIG. 26.

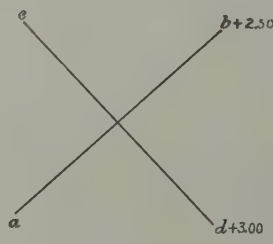

FIG. 27.

the cross is sometimes a difficult problem for the beginner, and the following rule will therefore be useful: *Put on a sphere equal to the strength of either, but generally the weaker meridian; add a cylinder with its axis corresponding to that same meridian whose strength (with the correct sign) is equal to the difference between the two meridians.* It is essential that the cylinder be of the proper sign, so that the combined strength of the sphere and cylinder will be equal to the strength of the opposite meridian. This gives the correction for one meter, if the examination has been made at that dis-

tance. By the addition of a —1.00 s. to this (explained farther on) the correction for distance is obtained.

To illustrate: By applying the above rule to the example given in Fig. 27, if the strength of the weaker meridian is chosen, the sphere will be +2.50 diopters; the axis of the cylinder will correspond with this meridian which lies at 45°. The strength of the cylinder is the difference between the strengths of the two meridians, which is +.50 diopter. The result is +2.50 s. ⌔ +.50 c. axis 45°. The +2.50 s. corrects all meridians except the stronger, which requires an additional +.50 c. with its axis at 45°, because the refractive strength of a cylinder is always at right angles to its axis.

If in the same case (Fig. 27) the stronger meridian be chosen, the strength of the sphere will be +3.00 diopters, the axis of the cylinder will correspond to that meridian, which is 135°. The strength of the cylinder is the difference between the strengths of the two meridians which in this case is —.50 diopter, and the result is +3.00 s. ⌔ —.50 c. axis 135°. Now, the +3.00 s. corrects all meridians except the weaker, which it overcorrects by .50 diopter, and the weaker meridian, axis 45°, therefore requires an additional —.50 c. axis 135°, to neutralize this overcorrection.

In a case where the result is represented by Fig. 28, a +2.00 diopter sphere is chosen as the proper strength which corrects all meridians except the one at 180°, which is seen by the figure to require —1.00 diopter, but as the sphere has added +2.00 diopters in that meridian, this result can only be obtained by the addition of a —3.00 c. axis 90°, which is the difference in strength between the two meridians. The result is +2.00 s. ⌔ —3.00 c. axis 90°.

In this same case (Fig. 28), if the —1.00 diopter is chosen as the strength of the sphere, all the meridians are corrected except the one at 90°, which, as seen, requires +2.00 diopters; but, as there is a —1.00 diopter lens already before it in the sphere the addition of a +3.00 c. axis 180° is necessary to correct it. The result is —1.00 s. ⌔ +3.00 c. axis 180°.

In Fig. 29, if —1.00 diopter is chosen as the sphere, it is the correct result for all meridians, except that a cylinder of —2.00 diopters strength is needed so as to obtain the required —3.00 diopters in the horizontal meridian, and the cylinder must be placed at axis 90°; the result here is —1.00 s. ⌔ —2.00 c. axis 90°.

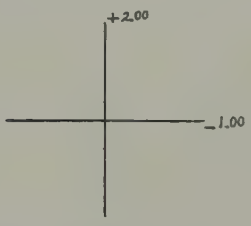

FIG. 28.

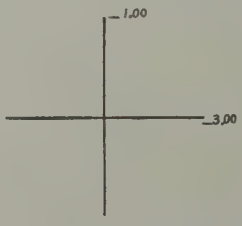

FIG. 29.

In the same figure (29), if a —3.00 diopter sphere is chosen as the strength, every meridian will be corrected except the one at 90°, which is overcorrected by —2.00 diopters, and will require a +2.00 c. axis 180° to correct it, giving a —3.00 s. ⌔ +2.00 c. axis 180°.

The reader will have noticed ere this that in every case two prescriptions whose refractive strengths are equal may be taken off the cross. EVERY PRESCRIPTION HAVING BOTH A SPHERE AND CYLINDER, OR A CYLINDER ALONE, MAY BE TRANSPOSED OR CHANGED INTO AN EQUIVALENT SPHERE AND CYLINDER. THE CYLINDER IN EITHER PRESCRIPTION WILL ALWAYS BE OF THE

SAME STRENGTH BUT WITH OPPOSITE SIGN, AND AT THE OPPOSITE AXIS TO THAT OF THE OTHER. THE DIFFERENCE IN STRENGTH BETWEEN THE SPHERES USED IS ALWAYS EQUAL TO THE STRENGTH OF THE CYLINDER.

In taking a correction off the cross, it is always well to think of the sphere as having the same strength in all meridians. But if one meridian is stronger, or weaker, than the one whose strength is chosen as the strength of the sphere, a cylinder is needed with its axis at right angles to that meridian, and its strength must be equal to the difference.

In a case where all meridians are alike, a sphere whose strength is the same as any meridian will correct all, and no cylinder is necessary.

It must be remembered that while two prescriptions are always possible when a combination of a sphere and cylinder is needed, it is nearly always better to give one than the other. It is better to give a simple cylinder than a sphero-cylindrical equivalent. It is cheaper, lighter, and usually better borne by the patient,—*e. g.*, give a +1.00 c. axis 90°, rather than its equivalent +1.00 s. ⌔ —1.00 c. axis 180°. For the same reasons it is usually more satisfactory to give the sphere corresponding to the meridian of the lowest amount of ametropia,—*e. g.*, in Fig. 27, +2.50 s. ⌔ +.50 c. axis 45° is better than +3.00 s. ⌔ —.50 c. axis 135°.

It is easy for the beginner to transpose any combination of sphere and cylinder into its equivalent by first putting it on the cross. Draw one line in the direction of the axis of the cylinder and the other at right angles to it. The strength of the sphere, since it lies in all meridians, can be marked at the end of each cross line. The strength of the cylinder must be marked at the end

of the cross line which lies opposite to the direction of its axis, since the strength of the cylinder is at right angles to its axis. The total strength of each meridian is now marked at the ends of the cross lines, and the same prescription or its equivalent can now be taken off the cross. Put +3.00 s. ⌔ —1.00 c. axis 180° on the cross. Taking it off the cross, two results are obtained,—viz.: +2.00 s. ⌔ +1.00 c. axis 90°, which is better than +3.00 s. ⌔ —1.00 c. axis 180°. (See Fig. 30.)

If in a sphero-cylindrical combination the sphere and the cylinder have the same sign, it is usually the better of the two possible prescriptions. If the sphere and cylinder have opposite signs, the cylinder being stronger than the sphere, as in mixed astigmatism, the prescription which has the weaker sphere is usually the better. If, however, the cylinder is weaker than the sphere, the sphero-cylindrical equivalent with like signs is usually much the better prescription.

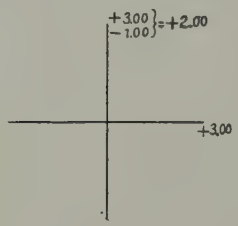

FIG. 30.

Our object in photoscopy is to locate the anterior focal point of an eye, or, in other words, the place where light rays reflected from the retina focus or cross. In myopia they focus without the aid of lenses, but in all other conditions lenses are required to obtain an anterior focal point. By the use of lenses the location of the anterior focal point can be changed.

Having determined the exact distance of the anterior focal point in front of an eye, and knowing the focal length of the lenses, if any are used, it is easy to calculate the strength of the lenses which would change its location to any desired distance in front of the eye. It

will be necessary to consider only the difference in focal lengths of different lenses.

Any eye having an anterior focal point is naturally myopic, or is made so by the aid of lenses. The distance of this focal point from the eye is the focal length of a lens which indicates the amount of myopia present. Therefore, the addition of a minus lens, whose focal length is the same as the distance of the anterior focal point from the eye, will permit the eye to see at infinity. The myopia has been neutralized, and the eye has no longer a finite anterior focal point. This is the same principle by which a plus lens is neutralized by combining with it a minus lens of the same strength.

Thus, if the anterior focal point be at one meter (approximately 40 inches) in front of an eye, the same distance at which a +1.00 diopter or 40-inch spherical lens would focus parallel rays of light, the eye is 1.00 diopter myopic; by placing a —1.00 s. in front of it, the distant correction will be obtained. The following examples illustrate the above principles:

1. If the anterior focal point is at a distance of one meter (40 inches) with no lens before the eye, it is one diopter myopic; therefore, the correction of the eye for the distance will be a —1.00 spherical lens.

2. If the anterior focal point is found to be at a distance of one meter with a +1.00 s. before the eye, the correction for distance is ascertained by the addition of a —1.00 s. But as this neutralizes the +1.00 s. before the eye, no correcting lens is needed, and the eye is emmetropic.

3. If the anterior focal point is at a distance of one meter with a +3.00 s. before the eye, the correction for distance is found as in the above two examples by the

addition of a —1.00 s. But as this only neutralizes +1.00 diopter of the total +3.00 diopters, the remaining +2.00 s. is the correction for the distance, and consequently the eye is 2.00 diopters hypermetropic.

4. If the anterior focal point is at a distance of one meter with a —3.00 s. before the eye the correction for distance is again found by the addition of a —1.00 s. to that already in front of the eye. The sum of the two lenses is a total of —4.00 diopters, the correction for distance, and the eye is 4.00 diopters myopic.

5. If the anterior focal point is found at a distance of one-half meter (20 inches), which is the focal length of a +2.00 diopter (about 20 inches) spherical lens, the correction for distance would be found by the addition of a —2.00 s., because it neutralizes the 2.00 diopters of myopia present.

6. If the anterior focal point is found at a distance of two meters (80 inches), which is the focal length of a +.50 diopter (about 80 inches) lens, the correction for distance will be the addition of a —.50 diopter lens to that already before the eye, as it neutralizes the .50 diopter of myopia present.

In finding the correction for distance the change is always made in the sphere and never in the cylinder,—*e. g.*, if the lenses before an eye for one meter were +2.00 s. ⌓ +.50 c. axis 90°, then by adding —1.00 s. as the allowance for working distance, the strength of the correcting lenses for the distance will be found to be +1.00 s. ⌓ +.50 c. axis 90°.

It is always best for the beginner to find first the strength of sphere and cylinder for the working distance by taking the result off the cross, and afterward add the neutralizing lens as the allowance for working dis-

tance, in order to find the proper distant lens or lenses. The expert will do both processes at the same time, combining the two to find the proper sphere, then proceeding with the first to find the cylinder, as the second process has nothing to do with the strength of the cylinder.

To find the distant correction, always add a concave (—) sphere (as an allowance for the working distance) to the dark-room correction.

EXAMPLES.

Dark-room,	— 2.00	— .50	0.00	+ 1.00	+ 2.00
Allowance for working distance at 1 meter,	— 1.00	— 1.00	— 1.00	— 1.00	— 1.00
Distant correction,	— 3.00	— 1.50	— 1.00	0.00	+ 1.00

Dark-room,	— 1.50	s. ⊂	— .50	c. ax.	90
Allowance for distance,	— 1.00				
Distant correction,	— 2.50	s. ⊂	— .50	c. ax.	90

Dark-room,	+ 1.00	s. ⊂	+ .50	c. ax.	90
Allowance for distance,	— 1.00				
Distant correction,	0.00	⊂	+ .50	c. ax.	90

Dark-room,	+ 3.00	s. ⊂	+ 1.00	c. ax.	30
Allowance for distance,	— 1.00				
Distant correction,	+ 2.00	s. ⊂	+ 1.00	c. ax.	30

Dark-room,	— .50	— 0.00	+ 1.00	+ 2.00	+ 3.00
Allowance for working distance at ½ meter,	— 2.00	— 2.00	— 2.00	— 2.00	— 2.00
	— 2.50	— 2.00	— 1.00	0.00	+ 1.00

After placing the result in the trial frame, it is best to test each eye separately to ascertain if any change is desired either in the strength of the sphere or cylinder, or a change in the position of the axis of the cylinder, found by rotating the cylinder in the trial frame. It is advisable to use the crossed cylinder in making this subjective test. (See *Ophthalmic Record*, February, 1904, for Author's article.)

Cycloplegics.—The question of the use of drops in order to paralyze the accommodation and dilate the pupil—cycloplegics which are also mydriatics—is of great importance. Their utility depends chiefly upon the fact that, if properly administered, the accommodation is temporarily suspended, the eye thus being in a condition of rest and unable to change its refractive strength. Under their influence the static, cycloplegic correction is obtained, and not the partial and ever-changing correction usually demanded by the otherwise capricious and inconstant eye. Uniform and complete paralysis must be obtained, for, if certain parts of the ciliary muscle remain more active than others, temporary astigmatism will be produced. A common error is the belief that dilatation of the pupil is the prime object sought. While it is true that a moderate dilatation is desired, the complete dilatation produced by all known cycloplegics is usually a source of annoyance, confusing the appearance in the central area and exposing peripheral areas that the patient does not use when the pupil is its normal size. It is, however, almost impossible to make the test correctly when the pupil is less than 4 millimeters in diameter.

The following is my method of using the drops (cycloplegics). Usually in patients under fifteen years of age one drop of an aqueous solution of the sulphate of atropin, varying in strength from one-fourth to four grains to an ounce, is dropped in the outer corner of each eye three times a day, after meals, for four consecutive days. If the lids are immediately closed after placing a drop in the outer corner of the eye sac, a thin layer of the liquid is immediately spread over the surface of the cornea and eyeball. Gentle pressure by the

finger over the inner ends of the lids for a minute or so prevents the solution from draining into the nose, which might produce toxic symptoms.

Atropin is also used,—

1. In patients over fifteen years of age if of a highly neurotic temperament.

2. In those who complain of previous failures in obtaining satisfactory lenses.

3. When homatropin has failed to give satisfactory results.

4. In those where a thorough rest of the eyes is indicated because of a woolly chorioid, flannel-red fundus, shot-silk retina, fluffy eye ground, or slight lenticular striations.

In patients over fifteen years of age, not included in the above category, one drop of an aqueous solution of homatropin hydrobromid, four grains to the ounce, is dropped in the outer corner of each eye two or three times, at intervals of five minutes, the night before, if the examination is to be made on the following morning. If the examination is to be made in the afternoon, a few drops are placed in the eye the morning of the same day. It is to be followed immediately before the examination by one drop, from six to ten times, at intervals of five minutes between each drop. During this treatment the patient with closed lids is seated in a darkened room. The examination does not take place until half an hour after the last instillation.

In patients over forty, the tension should be carefully determined and the danger of glaucoma considered, also the effect on lactation in nursing mothers. If there in an increase in the intraocular tension mydriatics are always contraindicated.

In cases of aphakia, and in most people over sixty years of age, if the pupil is not less than four millimeters in diameter, or is made so by the use of a few drops of a two per cent. hydrochlorid of cocain, or by a one per cent. each of cocain and euphthalmin solution, good results can be obtained without the use of any cycloplegic. In cases of myopia and mixed astigmatism with a fair-sized pupil, good results may sometimes be obtained without the use of a cycloplegic. However, the result is always more satisfactory with a cycloplegic, especially as these patients are usually more comfortable after the enforced rest of the eyes; and myopic cases, on account of the proximity of the near and far points, do not suffer much annoyance from their use.

No arbitrary rules can govern each individual case. Many things are to be considered in the selection and use of the proper cycloplegics, different examiners selecting different drugs, and using them in a quite different manner. Many prefer to use the drugs in the form of small soluble discs which are placed in the lower cul-de-sac, as recommended by Dr. Casey A. Wood. The writer sometimes uses homatropin even in children with good results.

The completeness of the paralysis of accommodation does not depend solely on the age of the person, but also on the condition of the ciliary muscle and general resisting powers. A bookkeeper at fifty years of age, who is overworking his eyes, may require a stronger cycloplegic than many young people. Homatropin, used as above described, is preferable in the great majority of cases, when the tension is not high, and other objections to its use are not present.

The Concave Mirror.—The same conditions ob-

tain with the concave as with the plane mirror, with the following exceptions:

1. The essential difference between the use of the plane and concave mirror is that with the latter the rays of light may and should focus before reaching the patient's eye, while with the former they cannot. The following points should therefore be observed, otherwise the rays will not focus before reaching the patient's eye, and the test would then be the same as with the plane mirror:

(*a*) The examiner must be seated at a greater distance from the patient than the focal length of the mirror.

(*b*) The focal length of the mirror—eight to ten inches—should be much shorter than the distance at which the examination is usually made (forty inches, or one meter).

(*c*) It is usually best to place the source of light behind, either above or to the side of the patient's head, as it is possible to have the source of light so near the mirror that the rays will not focus before reaching the patient's eye.

(*d*) The distance of the examiner should be maintained as nearly constant as possible, for even slight changes give rise to great differences in the brilliancy of the light entering the patient's eye. If a movement is made toward the patient, it is also toward the source of light, and there is danger of getting so near that the light rays will not have focused before reaching the patient's eye.

2. The examiner's eye and the anterior focal point of the patient's eye are made to coincide by the use of lenses, and preferably not by the examiner changing his position.

3. The source of light should be much larger than when using the plane mirror. If a light screen, which is not necessary but desirable, is used, the opening should be at least 30 millimeters in diameter.

In tilting or rotating the concave mirror, the light will move on the face with the movement of the mirror, as with the plane mirror. In addition, the small light images on the surfaces of the cornea, lens, and trial lenses, are also noticed. But the central light area in the pupil with which the examiner is chiefly concerned moves against the light on the face in emmetropia, hypermetropia, and in myopia of less than one diopter; and with the light on the face in myopia over one diopter if working at a distance of one meter. The relative movement of the light on the face, and the central light area in the pupil, with the concave mirror, is opposite to that (the reverse) with the plane mirror. When the central light area is moving against the light on the face with the concave mirror, convex (+) lenses are indicated; when the motion is with, concave (—) lenses, until the usual signs of being at the anterior focal point of the eye are noticed.

It is usually best, in determining the exact correction, to find two lenses of as nearly the same strength as possible, with one of which the light moves with the light on the face, and with the other, against. If these opposite movements are at about the same rate, a lens midway in strength between the two used would cause the anterior focal point of the meridian examined to coincide with the examiner's eye.

Aids to Accuracy.—In order that a satisfactory and accurate result may be obtained, not only the conditions

already noted but also those about to be mentioned, should be carefully fulfilled:

1. The examination room should be dark, with all light excluded except the artificial one used, which should be covered with a proper chimney or screen, in order that the portion of the retina surrounding its illuminated area may be as dark as possible, thus contrasting these two areas and making the margin between them more distinct. The room should be large and easily ventilated, so as to be more comfortable for both patient and examiner than the usual small sweat box or small closet arranged in a corner. The consultation room is readily converted into a sufficiently dark room by means of thick, black curtains, so arranged before the windows on horizontal steel rods that by the use of cords and pulleys two or more windows can be easily darkened by one short pull, the curtain sliding from side to side instead of from top to bottom.

2. The source of light should be as brilliant as possible, with its brightest part opposite the aperture in the shade, the size of which is governed by a diaphragm. A 5-millimeter opening is usually the best when working near the anterior focal point of a meridian. Some examiners, and nearly all beginners, prefer a larger aperture, which is perhaps better when working at a distance from the anterior focal point.

3. The source of light should be supported by a freely movable bracket, so that its distance from the plane mirror may be easily regulated according to circumstances. When working near the anterior focal point of a meridian in determining the correction for that meridian, it is best to have the light near the mirror, so that the position of its image, which appears to be behind the

mirror, will more nearly coincide with the anterior focal point. By this means, it is as near the conjugate focus of the retina as possible, thus insuring the best focus (smallest, with best-defined edge) of the light on the retina, and consequently a well-defined anterior focal point. If the anterior focal point of a meridian is considerably beyond the mirror, it is well to place the light farther away, so that its image, which will now be farther behind the mirror, will be nearer this conjugate focus of the retina. For this reason the light will more nearly focus on the retina. If the examiner is one meter (forty inches) distant from the patient, and the source of light above, or at the side of the patient's head, fifty inches from the mirror, the image of the light will appear to be fifty inches behind the mirror, or ninety inches from the eye. Now, if the light is placed five inches from the mirror, the image of the light will be forty-five inches from the eye or one-half the distance it was in the former case. The light entering the patient's eye in the latter case will be four times more brilliant than in the former, and if the anterior focal point was forty-five inches from the eye, there would be a perfect focus on the retina. (See pp. 37, 38.) The nearer the light is to the mirror, and the nearer the mirror to the eye, the more brilliant the light entering the patient's eye; and the more nearly the position of the apparent source of light and anterior focal point of a meridian coincide, the better the focus of light on the retina in that meridian.

4. The size of the opening in the light screen may vary. Experts usually prefer a small opening of five millimeters or less, beginners a large opening of ten

millimeters or more. Theoretically, the smaller the opening the better, so long as it is larger than the sight hole in the mirror, as thereby a smaller and more distinct retinal illumination may be obtained.

In determining the direction or axis of one of the chief meridians in regular astigmatism, when near its anterior focal point, it is best to have the apparent source of light coincide as nearly as possible with the anterior focal point of the opposite meridian. If located near the anterior focal point of the most myopic (original or produced) meridian, the source of light should be moved farther from the plane mirror, so that the apparent source of light behind the mirror may more nearly coincide with the anterior focal point of the opposite, least myopic, meridian. In this way the retinal illumination will be smallest in the least myopic meridian, of an elliptical shape, with its long axis corresponding to the most myopic meridian, thus aiding in the production of a more clearly defined apparent bar of light in the most myopic meridian. In the same way in working near the anterior focal point of the least myopic meridian, the concave mirror may place the apparent source of light near the anterior focal point of the most myopic meridian, forming an elliptical shaped illumination on the retina with its long axis in the least myopic meridian, thus assisting in more clearly defining the apparent bar of light in the least myopic meridian. For example, if located near the anterior focal point of the horizontal meridian with a bar of light extending across the pupil in that meridian and moving vertically with the light on the face with the plane mirror, the apparent source of light may be placed nearer the anterior focal point of the vertical

meridian by moving the source of light farther from the mirror, thus increasing the distance between the apparent source of light and the observed eye. If the apparent source of light and the anterior focal point of the vertical meridian are made to coincide, an elliptical area of illumination will be formed on the retina in the horizontal meridian. Light passing out of the eye from such an illumination will more clearly give rise to the appearance of a bar of light in the horizontal meridian, as there will be much diffusion in the horizontal and little in the vertical meridian. When the surgeon is located at one, and the apparent source of light at the other anterior focal point of one of the chief meridians, the bar of light appearance, apparently seen in the pupil when regular astigmatism is present, is most distinct.

Since the apparent source of light is behind the plane mirror, this form of mirror is usually best to determine the axis of a bar of light when located near the anterior focal point of the most myopic meridian, and to find the strength of the proper lens for each meridian by approaching its anterior focal point from the side nearest the observed eye. The reverse is true of the concave mirror as the apparent source of light is in front of it.

The distance at which the examination is made is largely a matter of individual choice. One meter is the usual distance, although in certain cases one-half meter is the best. The half-meter distance is sometimes to be preferred in cases of irregular astigmatism, and where the study of small areas of the pupil is imperative. It is possible to study conditions at this distance, which cannot be clearly observed at one meter; but the examiner must be careful to determine the

exact distance at which he worked when arriving at the final result. A mistake of a few inches is of considerable importance when working very near the eye, but of very little importance when one meter or more distant. (Randall, Transactions, Section of Ophthalmology, American Medical Association, 1894, p. 63.) Likewise, when very near the observed eye, the distance between the mirror and the source of light may give rise to a very imperfect focus of the light on the retina or diffused retinal illumination. It is often advantageous to vary the distance in each case during the progress of the examination. The writer has found the focal length of a +1.25 s., or approximately thirty-two inches, a good distance at which to use this test. He does not notice as many confusing areas at this distance as at one-half meter. Of course, a —1.25 s. must be added to the dark-room result, in allowing for the working distance, to find the distant correction.

The writer has an assistant aid him in making this test. The assistant measures, by means of a meter stick graduated in dioptric focal lengths, the distance between the patient's and examiner's eyes, in order that it may be correct, and places the required lenses in the trial frames as they are ordered by the examiner. When using the light close to the mirror, the examiner is enabled to move it closer to or farther from him with one hand, while he operates the mirror with the other. If the examiner does not possess the writer's shade, which he should, when working with the light close to the mirror, he can hold a large concave or plane mirror in the left hand so as to shade both his eyes from the bright light. At the same time he can reflect sufficient light on the trial case to enable his assistant to distinguish

the lenses. The mirror with which he makes the test is held in the other hand, and being well in front of the eye, receives the brightest part of the light past the edge of the other mirror. Since both the examiner's eyes are now in comparative darkness, they are not so quickly fatigued. Many give up the use of this test because of the discomfort caused by the bright light, and others make the test in too great haste for the same reason; but, if the above-mentioned shade is used, no difficulty will be experienced in this respect.

In this connection it might be well for the author to state his results with this test in actual practice, as it is only possible to locate approximately within narrow limits, never perfectly, the anterior focal point. In a series of ten cases he usually gets accurate results within one-eighth of one diopter in five; in four others approximately correct results, so that the test is of the very greatest service in these cases. In the remaining case a good result is not obtained, but, nevertheless, it is usually of considerable aid. He has, unfortunately, never had time, in actual practice, to make afterward a more thorough test of a sufficient number of these last-mentioned cases to determine just why the test has failed. No doubt, in some cases sufficient time and care were not taken.

Auto-photoscopy.—Dr. Edward Jackson, in the recent edition of his work, devotes a chapter to auto-skiascopy, and it has also been mentioned by Dr. Charles A. Oliver in Norris and Oliver's "System of Diseases of the Eye." In this test, one eye simply studies the refraction of the other through the medium of a mirror. Either a plane or concave mirror may be employed. The chief difference from the ordinary

test lies in the fact that the distance between the observing and observed eye is changed twice as rapidly in this case by any movement of the surgeon toward or away from the mirror, as it is when the surgeon moves toward or away from a patient. The distance from the observed to the observing eye is twice the distance from the observing eye to the mirror.

Relative Advantages of Plane and Concave Mirrors.—When working near the anterior focal point of the weakest, least myopic meridian, by using the concave mirror the apparent source of light, or image, is brought nearer the anterior focal point of the strongest, most myopic meridian. Thus, a better focus of the light on the retina in the most myopic meridian, and sometimes a better defined bar of light, will be the result.

Since the apparent source of light is behind the plane mirror, it is better when working near the anterior focal point of the strongest meridian, for the same reason that the concave is better when working near the weakest.

In positive aberration, the concave mirror places the apparent source of light nearer the focal distance of the large peripheral part of the lens, and a better focus is obtained on the retina.

In negative aberration the plane mirror places the apparent source of light closer to the focal point of the periphery of the lens, and thus produces a better focus on the retina.

The distance between the examiner and patient and between the mirror and the source of light, with the plane mirror, may be easily changed; but this is not always so readily done with the concave, an advantage

in favor of the plane mirror. If the examination must be made in a partially darkened room by an ordinary unshaded source of light, the concave mirror is probably better than the plane, which latter is usually to be preferred under proper conditions. The anterior focal point when near the surgeon's eye and the apparent source of light can be more nearly approximated by the plane mirror; hence it is to be preferred in determining the correcting lens.

The writer first learned the use of the plane mirror with the light close to the mirror, and of course usually prefers that method, and thinks it the better one. Each method has its good and bad features, but the writer still clings to the first used just as one usually prefers to use his own ophthalmoscope rather than any other.

CHAPTER V.

HISTORY.—NAME.—OTHER INSTRUMENTS.

History.—On December 12, 1859, Bowman (The Royal Ophthalmic Hospital Reports, vol. ii, No. 9, p. 157) called attention to the characteristic appearances of conical cornea when the ophthalmoscopic mirror is tilted or rotated. Donders, 1864, in his work translated for the new Sydenham Society by Dr. Moore, of Dublin, quotes Bowman as claiming to find regular astigmatism of the cornea and the direction of its chief meridians. He rotated the ophthalmoscopic mirror—while held at a distance of two feet from the eye under examination—in different meridians and observed what he called a linear shadow in some meridians of the pupil which did not appear in others.

The use of the ophthalmoscope for the detection of conical cornea and irregular astigmatism became popular, but its use in regular astigmatism was almost entirely neglected. Mr. John Couper, in 1872, at the Fourth International Ophthalmological Congress (see Trans., p. 109) read a paper entitled "The Ophthalmoscope as an Optometer in Astigmatism," and claimed that the greater dispersion in one meridian than in the opposite gave rise to the linear shadows, and only established the fact that astigmatism is present.

It was known soon after the discovery of the ophthalmoscope by Helmholtz in 1851, that if an erect image of the fundus was seen at some distance from the eye by

the direct method, it indicated hypermetropia, and an inverted one indicated myopia. Couper further described a modification of the ordinary use of the ophthalmoscope, already referred to by Donders,—the reversal of the image of the retinal vessels and their distortion so as to be unrecognizable in certain meridians.

(Every one seems to have been totally unaware of the observations of Bowman and Donders until Parent called attention to them in a paper written in 1880.)

In the meantime, Cuignet of Lille, one of Professor Galezowski's assistant editors of the *Récueil d'Ophthalmologie*, was doing original work with this test, since he was not acquainted with Bowman's or Donders' observations. As he did not possess a good theoretical knowledge of optics, much of his labor and enthusiasm were misdirected. He thought that the phenomena of the test were solely of corneal origin, since he still wrongly believed that ametropia was due only to different shapes and curves of the cornea. He wrote two papers on the subject, in 1874, claiming that the test gives a practical method of measuring the amount of myopia, hypermetropia, and astigmatism, and for the first time mentions lateral movements of the mirror. He further described the lateral movements, in 1877. Previous to this he had revolved the light on the eye, but had not moved it straight across the eye in the direction of a certain meridian.

Little attention was given the test until Cuignet's pupil, Mengin, introduced its use at Galezowski's clinic in Paris and demonstrated it to Drs. Parent and Landolt. In 1878 Mengin wrote a paper describing the test and gave entire credit to Dr. Landolt for explanations of the causes of the observed phenomena. Dr. Parent,

well trained in optics, urged its advantages and explained the test in a series of excellent articles published in the *Récueil d'Ophthalmologie* in 1880–81, pp. 65 and 229. It now became a more popular test. Lytton Forbes, at that time a clinical assistant in Moorfields Hospital, in the Royal London Ophthalmic Hospital Reports for 1880 (p. 62), gives a minute account of the various phenomena in the pupil, but he did not give a full explanation of their optical significance, since at that time he did not seem to understand thoroughly the theory and practice of the test.

In 1881, A. Stanford Morton gave a full description of the test in his work on the refraction of the eye. In 1882 the profound scholar, Charnley, fully explained its optical principles in the Royal London Ophthalmic Hospital Reports (x, 3, p. 344). In the same year, Juler described it in the *Ophthalmic Review* (vol. i, p. 327).

In 1882 Chibret (*Annales d'Oculistique*) pointed out for the first time the advantages in using the plane mirror, and in 1883, J. B. Story, of Dublin (*Ophthalmic Review*, vol. xi, p. 228), advocated the use of the plane mirror at a distance of four meters from the patient.

In 1885 Jackson (*American Journal of the Medical Sciences*, April, 1885) gave a clear account of the use of the plane mirror, and he added much to our knowledge by many different contributions (see Bibliography), and especially by the various editions of his excellent monograph on "Skiascopy."

Dr. James Thorington deserves special mention for inventing different appliances that make the test more effective and practicable. He has done much to make

examination with the plane mirror popular, and has written an excellent working manual.

Dr. A. R. Baker, of Cleveland, Ohio, was one of the first to describe and recommend the test in this country.

(For a rather complete record of the literature on this subject, consult the appended Bibliography.)

Name.—Bowman did not propose any special name for this test. Cuignet, who thought that the play of light and darkness in the pupil depended entirely on the curvature of the cornea, named it "keratoscopie." His premises were wrong and consequently his conclusions. Parent called it "retinoscopie" (retinoscopy), which really means to observe or to study the retina,—actually ophthalmoscopy. This is a misnomer, as the light may fall on the chorioid, sclera, or optic nerve ending. It is a much, but improperly, used term. Chibret proposed the name of "fantoscopie retinienne," which Priestley Smith translated into "the shadow test," because it was thought to be the movement of a shadow. Skiascopy has the same meaning. It is not the study of a shadow, but of light, and these terms are open to criticism on this score. Hartridge proposed "umbrascopy;" Landolt, "koroscopie;" Galezowski, "dioptroscopie." They are all open to objections. Dr. C. A. Oliver has suggested "fundus reflex test," a good name but unnecessarily long. "Retinophotoscopy" is objectionable for the same reason. Marginal or border test has been suggested, but is also open to objection.

The writer has ventured the name "photoscopy," meaning "to examine or look at light," and thinks it the best name for the test for the following reasons:

1. It is a light test in every particular. There is a

source of light from which light is reflected into the eye, causing an area of light on the retina, and, from this light area, light rays are again reflected. The examiner (as a part or all of these rays of light enter his eye, after undergoing more or less refraction while passing out of the patient's eye) observes the size, shape, direction, and rate of movement of this area of light—the projected image of the retinal illumination apparent in the pupil.

2. Light is an oscillatory movement of a supposed fluid called ether, and darkness is the absence of this movement. It is far easier to consider a positive than a negative condition.

3. Shadow is the interception of light by some object, and as no object intercepts the light passing out through the pupil, no real shadow is ever present (certainly the mirror is not employed to throw shadows). It is true that the greater part of the retina is in comparative darkness, but only a small area of this dark part enters into the test and the illuminated area *only* may have its location changed. The shadow surrounding the central light area, or image, might be spoken of as an image of a portion of the dimly illuminated part of the retina. On the other hand, the light area or image of the light illumination on the retina is always seen and studied. Nothing else can be seen when at the point of reversal, or anterior focal point of the eye. In some cases, when at the anterior focal point of the eye, the whole pupil is occupied by an image of only a part of the retinal illumination. The pupil is always filled with light, and the reason certain portions may, and often do, appear dark is because the light, passing from the bright retinal illumination through these portions of the pupil, does not enter the examiner's eye. If the

examiner moves his eye to a different position, the light area will displace the dark area in a corresponding portion of the pupil.

4. A short, euphonious word is needed to describe the test, which can be easily applied to its peculiar instruments, use, user, and subject: photoscope, photoscoped, photoscopist, and photoscopy.

FIG. 31.—Jennings' photoscopic disc.

Other Instruments. — Many different supports for lenses have been suggested, in order to save time and make it easy for the examiner to place the desired lenses promptly, and with as little inconvenience as possible, before the patient's eyes. Dr. H. V. Würdemann's very convenient hand photoscopic disc has already been described (Fig. 7). The Geneva hand disc differs from the Würdemann instrument only in having the convex lenses on one standard, and the concave on another. An excellent double-hand photoscopic disc was designed in 1903 by J. E. Jennings and is made by A. S. Aloe Co., of St. Louis (Fig. 31). It consists of two aluminum frames with a one-inch opening down the middle for the nose, one holding 18 convex and the other 18 concave lenses, placed so that the instrument, which is held in position by the sides, can be used with varying pupillary distances. Many revolving discs containing

lenses have been arranged by Doyne, Couper, Geneva Optical Company, Jackson, Burnett (Transactions American Ophthalmological Society, 1888, p. 223), Haines (*Ophthalmic Review*, 1886, p. 282), Hardy, C. H. Crain, and F. G. Murphy. Lambert (Transactions American Ophthalmological Society, 1894, p. 196) describes an instrument containing a very complete series of lenses so that both spheres and

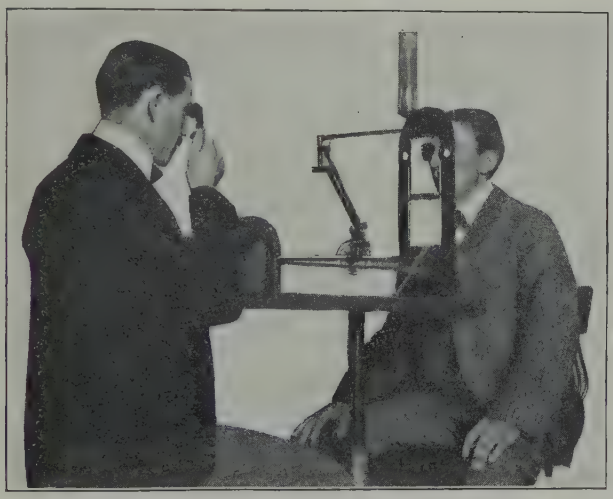

FIG. 32.—Jennings' disc.

cylinders may be quickly placed before the eye. One of the best instruments on the market is the Meyrowitz refractometer. Probably the most complete revolving photoscopic disc is that of Jennings (*American Journal of Ophthalmology*, November, 1896, and April, 1899). It is constructed on the same principles as the Morton ophthalmoscope. The examiner, by turning a wheel on the lower part of the instrument, which rotates the battery of lenses, can place any desired

lens before the observed eye. The Cross retinoskiameter is quite ingenious.

In a very complete instrument, the examiner is often compelled to run over a large number of lenses before finding one of the desired strength, and this naturally takes much time, defeating the very object for which such instruments are made. The chief objection to most of these instruments is the too great distance between the lenses and the eyes of the patient. To use a small series of lenses giving an approximate correction quickly, and followed by lenses from the trial case, in a properly ad-

FIG. 33.—Axonometer.

FIG. 34.—Axonometer.

justed trial frame, would seem to be the best method. These instruments are a convenience and not a strict necessity. With the more complex, since the examiner is unable to change his distance from the patient, it will probably often be wise to use the concave mirror with the light behind the patient's head. The ordinary trial frame, properly adjusted, keeps the lenses in a constant relative position to the patient's head, so that a slight movement of the head does not decenter the lens appreciably, as it does with other supports. When the examiner has learned to estimate approximately the

amount of ametropia present, when looking at the reflex, he can make considerable changes in the strength of the lenses until an approximate correction is obtained, and then use lenses more nearly of the same strength. A large number of lenses in a trial case is a great convenience,—*e. g.*, if 4.75 s. and 5.25 s. lenses can be used it is easy to observe contrasts in the direction of movement of the central light area and thus determine when a 5.00 s. is required.

In a case with a high degree of hypermetropia which is detected at the first glance, a +3.00 or

FIG. 35.—Finch's disc.

+4.00 s. is first placed before the eye making an approximate correction; lenses of nearly the same strength are afterward used until the correct one is obtained. In such cases it is unnecessary and unwise to put on a series of +.50 s., +1.00 s., +1.50 s., +2.00 s. lenses. Proficiency comes with practice, and the expert usually places but few lenses before the eye.

As it is sometimes difficult by looking at the trial frame in the dark room to determine the direction or axis of the bar of light in astigmatic cases, Thorington (*Medical News*, March 3, 1894) has suggested small

black metal discs of the same size as the ordinary trial lens, to be placed in the front opening of the trial frame. When the bar of light is most distinct in a certain meridian, the axonometer (Figs. 33 and 34) is turned until the two heavy white lines appear to lie in the same direction. Dr. Prince (*Ophthalmic Review*, July, 1894) suggested a somewhat similar disc called an "Inclinometer." R. B. Finch suggested one with a wire stretched across, which may be made to conform to the direction of the bar of light (Fig. 35).

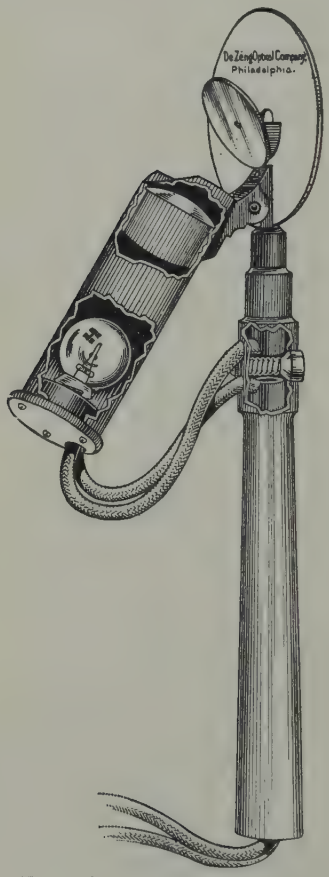

Fig. 36.—De Zeng's luminous photoscope.

H. Wolff presented an electric photoscope at the Heidelberg Ophthalmological Congress in 1896. De Zeng has also designed an excellent instrument of this type. In this instrument the distance between its convex lens and lamp may be varied so as to give the effect of either a plane or concave mirror at different distances from the source of light. These instruments are particularly useful when working in a room not specially equipped for this test (Fig. 36).

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